



Research at USAFA 2012

The cover photo is of a water-gel sphere made of sodium polyacrylate being held by Capt Samantha Adee (DFC).

Photograph was taken by Lt Col Royce Beal in the USAFA Department of Chemistry.



TABLE OF CONTENTS

Introduction.	1	Division of Humanities	30
Letter from Lt Gen Mike Gould, Superintendent of the USAF Academy.	2	Division of Social Sciences	32
Letter from Brig Gen Dana H. Born, Dean of the Faculty	4	Eisenhower Center for Space & Defense Studies	34
Academy Center for Cyberspace Research	6	Human Performance Laboratory	36
Academy Center of Innovation.	8	Institute for Information Technology Applications.	38
Academy Center for Unmanned Aircraft Systems Research	10	Institute for National Security Studies	40
Aeronautics Research Center	12	Laser & Optics Research Center.	42
Astronomical Research Group and Observatory	14	Life Sciences Research Center	44
Cadet Summer Research Program	16	Modeling and Simulation Research Center	46
Center for Aircraft Structural Life Extension	18	Scholarship of Teaching and Learning	48
Center for Character & Leadership Development	20	Space Physics & Atmospheric Research Center	50
Center for Physics Education Research	22	Space Systems Research Center	52
Center for Space Situational Awareness Research	24	Science, Technology, Engineering & Mathematics	54
Chemistry Research Center	26	USAFA Center for Oral History.	56
Department of Civil and Environmental Engineering	28	Funding Status for Research at USAF Academy	58

RESEARCH AT USAFA 2012

When you look through the lens of a kaleidoscope, the mirrors, colors, and angles collide to reveal hundreds of new images—shedding new light on the way we see the world.

Just like the kaleidoscope, the sponsored research program at the United States Air Force Academy (USAFA) reveals new experiences and scientific discoveries, with each of its facets mirroring the diversity, strengths, innovation, and commitment of the cadets who call USAFA home. This ever evolving arena offers cadets a chance to develop depth and dimension as future officers and leaders of character.

Multiple prisms focus the Academy’s mission to educate, train, and inspire men and women to become officers of character, motivated to lead the United States Air Force (USAF) in service to our nation. The Academy’s sponsored research program instills in cadets all of the elements of scientific inquiry, real-world research experiences, innovative approaches to teaching and learning, character and leadership development, and military discipline.

With one twist of the kaleidoscope, the Academy’s learning-focused methodology and faculty commitment offer cadets a nationally-recognized undergraduate education. Cadets have access to a more than \$73 million dollar research program, world-class labs and equipment, and professional Cadet Summer Research Program (CSRP) opportunities with the Department of Defense (DoD), the USAF, and private industry. Graduating cadets also have unprecedented opportunities for

placement at top graduate programs around the world including the University of Oxford (U.K.), Massachusetts Institute of Technology, and Stanford University.

Another twist of the lens reveals the discipline of training—in and out of the classrooms and labs. Discipline, commitment, and the ability to respond to emerging challenges are critical components in today’s USAF mission. The Academy’s research program develops officers of character, blending the oft hard-won lessons of research with the mentoring and guidance of seasoned military and private sector leaders via programs such as the Academy’s Center for Character and Leadership Development (CCLD) and its acclaimed National Character and Leadership Symposium (NCLS).

In the light of sun and another twist, the colors of the Academy’s kaleidoscope come into full view. Inspiration is revealed in cadets giving of their free time to support local Science, Technology, Engineering, and Mathematics (STEM) outreach efforts. It is also demonstrated in the heroic actions of faculty such as Department of Aeronautics assistant professor Lt Col Ryan Osteroots and his life-saving actions during the tragic aerial accident at the Reno Air Races in 2011. Inspiration is found every day in the halls, classrooms, and labs of the Academy. As a community, as a cadet wing, and as an institution of higher learning, Academy cadets and faculty embody integrity, service before self, and excellence in every endeavor they undertake.

Combined together, these images, colors, and experiences make USAFA Research, the Academy, and the nation a better place. This is Research at USAFA.

RESEARCH AT USAFA AND MEETING THE MISSION

With a research enterprise now exceeding \$60 million annually, the US Air Force Academy's sponsored research program is on the front-lines of educating the next generation of officers of character, equipped with sophisticated critical thinking skills and inspired to execute visionary leadership—characteristics that on today's complex battlefields will help them to anticipate and respond to evolving missions in air, space, and cyberspace.

Cadets today are immersed in complex summer research projects, national student paper competitions, and priceless one-on-one mentoring from leading experts and faculty in support of the Academy's mission to educate cadets.

The 20 research centers and institutes at USAFA offer cadets a diverse choice of real-world, AF Air Force mission-relevant research opportunities, as well as offering opportunities for cadets to mentor the next generation of potential cadets and Science, Technology, Engineering, and Mathematics (STEM) professionals via the Academy's regional

K-12 STEM Outreach Center. Cadets also benefit from the research efforts and opportunities offered via the USAFA Center for Character and Leadership Development including but not limited to participation in the National Character and Leadership Symposium. From the game-changing development of disruptive technologies in our Center of Innovation to the successful world's only undergraduate-only small satellite research FalconSat program, the opportunities are unlimited.

What this means to the Academy and more importantly, to the US Air Force, is the assurance that the continued quality of the long blue line of well-developed and educated officers of character is assured for our nation's future. I take no greater pride than during graduation when I know that the class members standing before me and their friends and families have contributed to the great academic mission of the Academy and are going forth as our best representatives in the diverse specialty areas for which we have prepared them. I know they will be beacons of leadership and innovation not only in their ser-

vice to the nation but also in service to our local and broader Air Force communities.

The Academy's research program plays a critical role in that preparation. Through trial and error, and success and failure, cadets have the rare opportunity as undergraduates to apply their knowledge to some of the most critical challenges facing today's Air Force and Department of Defense.

As new technologies emerge, cadets are given the opportunity to be on the very cutting edge, quickly becoming familiar with some of industry's most advanced research tools and labs. For example, cadets are conducting cutting edge nano-technology and meta-materials research in our Chemistry Research and Laser and Optics Research Centers. Recognizing that budget realities will require the Air Force to operate much of its aging fleet for years to come, cadets are today helping the Air Force manage that challenge by making life-saving research discoveries in the arena of aging aircraft analysis, structural integrity and maintenance programs. Simultaneously, cadets in our



Space Systems Research and Space Physics and Atmospheric Research Centers are designing, launching, and operating real-world, real-client Department of Defense small satellites and sensors in orbit and on the International Space Station.

This annual research report is but a glimpse into the many diverse and multi-disciplinary research successes achieved over the past academic year. I invite you to explore these wonderful and growing research centers and endeavors. I extend my thanks and praise to our many dedicated faculty for their guidance and commitment to our cadets. To our cadets, my congratulations for a job well done.

A handwritten signature in black ink that reads "Mike Gould". The signature is stylized, with a large, looping "G" at the end.

Lt Gen Mike Gould
Superintendent, USAFA

CUTTING EDGE RESEARCH ACROSS THE SPECTRUM OF LEARNING

As a 1983 graduate, I have come full circle from cadet to Dean of the Faculty and Austin Dusty Miller's quote on the Eagle and Fledglings statue rings as true today as it did when I was a cadet—"Man's Flight Through Life is Sustained by the Power of his Knowledge." The cycle of mentoring and leading our cadets, watching them become officers of character, like the Eagle to the Fledglings, is one of the most rewarding jobs in the US Air Force.

Under the guidance of our dedicated faculty, cadets have the chance to partake in the nation's #1 federally-funded undergraduate-only research program. With a research enterprise now valued at more than \$60 million, access to cutting-edge technologies and laboratory equipment, more than 400 professional researchers and faculty as mentors, and real-world cadet summer research and independent research projects; the research program at USAFA continues to evolve and contribute to our mission to educate, train, and inspire men and women to become officers of character motivated to lead the United States Air Force in service to our nation.

The research program at the Academy spans all of the disciplines from Aeronautics to English and offers all cadets the opportunity to apply the knowledge gleaned from coursework to real-world problems. The dedication of our faculty and the depth of our academic and research programs can be seen in the record number of cadets awarded graduate school slots for AY 2011-2012. Totalling 117, these graduate slots included our 37th Rhodes Scholar, two Marshall Scholars, and a record 26 graduates heading directly to Medical Schools including four nurse and one dental, for a total of 31 medical professional scholarships.

Via our Cadet Summer Research Program (CSRP) and our more than 120 Cooperative Research and Development Agreements (CRADAs), cadets have the chance to be involved in top US Government agency, Department of Defense, USAF, and industry projects that have the potential to save lives, save dollars, and contribute to private technology transfer. Some of the projects cadets are involved in include on-the-ground training opportunities such as the

NASA Orion Crew Exploration Vehicle parachute deployment research, coordinating on-board mission activities for sponsors for programs such as the multi-million dollar cadet-built CANARY sensor, which is mounted on the International Space Station, as well as cutting-edge renewable energy research programs for solar and bio-fuels, and more.

Our aim is not only enhanced education, but enriched character and leadership opportunities. Our character education and community outreach efforts are critical to helping our cadets be the best they can be as officers and individuals. The Center for Character and Leadership Development (CCLD) offers cadets and faculty the chance to learn from some of today's greatest examples of character leadership via the annual National Character and Leadership Symposium. The Academy's Center for K-12 Science, Technology, Engineering and Mathematics (STEM) Outreach and Research, funded by the Office of the Secretary of Defense's National Defense Education Program, has continued to expand its impact on hundreds of regional educators and thousands of



K-12 students. A Cadet Wing STEM Outreach Club has been established and cadets have volunteered several hundred hours of their time to support regional and USAFA STEM events.

It is all this and more that makes our USAFA Research program the success it is. This annual research report is only a small window into the diverse and meaningful learning-focused world of USAFA Research. I hope you enjoy this report as much as I have enjoyed watching our cadets grow as students and future officers and our faculty blossom with career-enhancing research opportunities.

A handwritten signature in black ink that reads "Dana H. Born".

Brigadier General Dana H. Born
Dean of the Faculty

ACADEMY CENTER FOR CYBERSPACE RESEARCH

Computer technology and the Internet have transformed our world. The United States relies heavily on cyber capabilities for critical infrastructures such as water and power, the financial system, transportation, communications, and military defense. These capabilities are highly vulnerable and are under constant attack. Cyber-crime, such as identity theft and corporate espionage, is estimated to have an annual global cost of \$114 billion. Cyber-terrorist threats are increasing as malicious code has become more sophisticated with the capability of shutting down or destroying national assets. Cyber warfare is a reality that threatens our national security. It can be conducted by anyone, anywhere, at any time, without requiring large military resources.

The Academy Center for Cyberspace Research (ACCR) develops cyber innovators to defend our Air Force and nation. Students learn, first-hand, the techniques and tools for conducting offensive and defensive cyber warfare, they study current cyber threats, they conduct research in current cyber topics,

and they practice hands-on cyber operations through simulated exercises. According to ACCR Director, Dr. Dino Schweitzer, “Cyber capability represents some of the greatest opportunities as well as some of the largest threats in the history of mankind. Cyber warfare is not an academic exercise. Preparing cyber warriors is crucial to the security of the nation.”

All Computer Science majors get the opportunity to experience cyber research in the Information Warfare class through small-team projects with a faculty mentor. Students are led through the entire research process from problem definition, literature review, project planning, data collection and analysis, to publication of results. Student projects in 2011 included biometrics, digital camera forensics, mobile security, DoD access control vulnerabilities, and social engineering. Two student projects were accepted for publication at computer conferences. An independent study student demonstrated the effectiveness of using visualization to detect network attacks and presented his findings with a poster at the Colorado Springs Undergraduate Research Forum.

Funded research projects included continued work on unkeyed jam resistant communication led by Dr. Leemon Baird and funded by AFOSR. Based on previous findings, researchers implemented algorithms on software radios demonstrating the feasibility and benefits of the approach for communication in a battlefield environment. Heike Siegmar, a visiting researcher from Germany, used her expertise in software radios to advance this project. DARPA funding provided resources to investigate the development of a provably secure DNS server. Led by Dr. Martin Carlisle, this project uses formal methods in Computer Science to provably demonstrate certain secure properties of a critical piece of software in network communication. Initial findings from this project have already led to two publications. A newly funded project by NSA is looking at the application of artificial intelligence techniques to monitor and control the national power grid. A neural network approach is being developed to investigate optimum strategies for dealing with intentional or unintentional faults in this critical infrastructure.



In addition to educating cadets through research, practical experience through hands-on activities provides students the opportunity to learn the principles of cyber warfare in a more realistic environment. The NRO-supported Cyber Warfare Club is open to students of all disciplines. Over 100 students learn cyber tools and techniques through hands-on cyber “pre-flights” designed to teach basic skills in network offense and defense. Students that demonstrate superior skills participate on the USAFA Cyber Competition Team coached by Dr. Carlisle. The team participated in fifteen competitions in 2011-2012, many of which included competing against international and graduate-level programs. Some of the highlights included being one of 12 undergraduate teams



making the national finals at the NYU Poly Cyber Security Awareness Week Capture the Flag Competition, finishing 5th out of 28 U.S. teams in the International Capture the Flag competition, and 53rd out of 472 teams in the Codegate 2012 Challenge. The team completed the year with a flourish by finishing 2nd at the National Collegiate Cyber Defense Competition held in San Antonio. “The team’s success”, said Dr. Carlisle “results from the incredible dedication of our students and their tremendous motivation and commitment to learning the skills they will need to defend our nation in the cyber domain.”

The greatest cyber competitive success of the year was accomplished by the Cyber Competition Team in conjunction with the Secure Networks class, also taught by Dr. Carlisle. The final class project is participation in the annual NSA-sponsored cyber competition between service academies known as the Cyber Defense Exercise (CDX). Student teams design and secure a network against attacks by the NSA Red Team. During the exercise, students must maintain running services, such as email and web service, while thwarting attacks by malicious users, malware, and malevolent insiders. The USAFA competitors finished first, besting all undergraduate and graduate participants, and winning the NSA Information Assurance Director’s trophy.

ACCR continues to look for ways to extend cyber research and education to more cadets as well as the larger Colorado community. Basic Cyber, a new summer program, teaches cyber operations topics to cadets of all disciplines. Outreach efforts such as regional seminars and competitions allow faculty and students to interact with other educators and practitioners. “Creating greater cyber awareness and fostering collaborations is a win for everyone” said Schweitzer.

ACADEMY CENTER OF INNOVATION

The Department of Homeland Security, Science and Technology Directorate funded Center of Innovation (CoI) at the US Air Force Academy (USAFA), established in 2008, is a leader in championing game-changing innovations for the United States Government (USG). The CoI has created an ecosystem comprised of public-private partnerships with market-shaping companies such as Intel Corporation and IBM Watson Research Center.

The value of these novel public-private partnerships is three-fold: the government is able to see into the future of market-shaping research technology; private industry gains insight into the technology needs of government; and USAFA Cadets gain unprecedented research opportunities with the private sector.

USAFA Cadet involvement is critical and is a prerequisite for every research relationship the CoI cultivates with its private industry research partners. USAFA Cadets are mentored by world-class innovators conducting cutting-edge research both at USAFA and within industry.

In October 2011, the CoI conducted the fourth annual Rare Event Scenario. The Rare Event Scenarios have two primary focuses—the field-testing of emerging technologies and the assessment of social collaboration strategies. Participants are tasked with collaborating through various types of multimedia to anticipate and prevent a simulated “Rare Event” such as 9/11, Oklahoma City, or Pearl Harbor.

By utilizing emerging social networking technologies, CoI researchers hope to increase collaboration by facilitating greater sharing of information and public alerts between individuals, communities, and the government. CoI believes that many communication challenges dealt with during the 9/11 attacks and Hurricane Katrina could be prevented in the future with the use of innovative communication technologies now under development by CoI partners.

The evolution of technology is facilitating new genres of communication. The market demand is being driven by the web 2.0/3.0 millennial generation, who view cyberspace as their natural habitat.

Today’s USAFA Cadets view cyberspace as their natural domain. A multitude of USAFA Cadets have been keenly impacted by the CoI’s efforts. “I was inspired to put my ideas to work and not restrict myself,” said an anonymous Cadet from Dr. Hepard’s Technological Innovation Management class. “Cadets have outstanding minds and the [Center of Innovation] Lab is something that should be taken full advantage of while at the Academy. I wish I had known about this place sooner,” added another anonymous Cadet.

The greatest focus of the October 2011 Rare Event Scenario was the value of 2D vs. 3D environments. The goal is to determine if 3D environments aid in social collaboration in a distributed fashion, specifically for First Responders and Edge Warfighters. The Rare Event Scenarios are analyzed by IBM Watson Center for Social Software.

“One of the most exciting things the Center of Innovation has to offer USAFA Cadets is the one-of-a-kind experience in the private sector. For me, it is



very rewarding to see these Cadets being mentored by and working alongside leading researchers who are focused on game-changing innovations. Our USAFA Cadets, through the CoI, are provided the tools to develop into leaders of character—leaders who will have a great impact on the evolution of the Air Force and DoD operations,” says Dr. Terry Pierce, Director of the Center of Innovation.

During the 2011-2012 academic year, the CoI sponsored 5 USAFA Cadets to conduct research with Intel Corporation’s leading scientists at Intel Research Labs in Hillsboro, Oregon. USAFA Cadets had the opportunity to study leading-edge futurism, anti-malware, compute continuum, software

router architecture and wearable displays. Feedback about USAFA Cadets is always impressive. “He’s simply fantastic and his time with me has been nothing short of delightful. He is very likely the best intern I’ve ever worked with. He’s smart, resourceful, motivated, intrinsically curious, organized, enthusiastic, articulate, and makes an excellent argument. He sought out what he needed, critically evaluated it and synthesized a lovely vision of the compute continuum for us,” said Intel Labs sponsor. In previous years the CoI has sent USAFA Cadets to study at Intel Corporation, IBM Watson Research Center and SHARP. Upon graduation, the CoI hopes USAFA Cadets can leverage their research experiences to champion solutions to tomorrow’s threats.

In addition, Dr. Pierce is regularly a guest speaker on disruptive innovations both at the USAFA and throughout the private sector. “Disruptive innovation is an improved performance along a trajectory that traditionally has not been valued. Fostering a disruptive innovation cauldron for USAFA Cadets provides the exposure to game-changing technologies and the new skill sets for USAFA Cadets to become great leaders of character in today’s ever changing technological domain,” states Dr. Pierce. The CoI fuels that cauldron through its emerging private and public sector innovation model.

At the time of this report, the CoI was working with Intel Corporation Research Labs to build the CoI Anti-Malware Laboratory—the first anti-malware research lab outside of Intel. This unique research laboratory will create a test bed for the most current hardware and software innovations being researched at Intel Research Labs and give USAFA Cadets and our USG agency partners unprecedented access to anti-malware research technology. Though Intel’s anti-malware technology research is strictly limited to defensive efforts, the CoI Anti-Malware Laboratory will afford USAFA Cadets and faculty the opportunity to run malware experiments in a controlled setting. The public-private goal for the CoI Anti-Malware Laboratory is to compliment and supplement existing academic and military training programs in the area of cyber-attacks and defense for the modern cyber warrior.

ACADEMY CENTER FOR UNMANNED AIRCRAFT SYSTEMS RESEARCH

The ability of the Air Force to provide timely, integrated intelligence, surveillance, and reconnaissance (ISR) to Department of Defense assets has become crucial to mission success and to saving lives. The Academy Center for Unmanned Aircraft Systems Research (ACUASR) has been leading the way to meet this critical operational need through ground-breaking research on a variety of new technologies including multiple, autonomous remotely piloted aircraft (RPA) operations for intelligence, surveillance, and reconnaissance and RPA sensor delivery.

Understanding ISR requirements and their impact on the next generation of RPA, formerly known as unmanned aerial systems (UAS), are crucial for today's operations and tomorrow's Air Force leaders. In 2011, the Air Force Posture Statement named Intelligence, Surveillance, and Reconnaissance (ISR) Systems as one of the five USAF acquisition priorities.

Led by Dr. Daniel Pack, the Center is multidisciplinary by nature, employing faculty and cadets from

Aeronautical Engineering, Electrical and Computer Engineering, Engineering Mechanics, Systems Engineering Management, and Systems Engineering. The interdisciplinary aspects of RPA design and the increasing opportunities for RPAs in both military and civilian applications offer complex classroom and research challenges to cadets and require them to solve problems on a myriad of levels. "As the cadets strive to solve these problems, I often hear them saying the problem is too complex and too difficult at the start. But as the cadet project teams work together, they begin to understand their capabilities and recognize how much they can accomplish," said Pack. "They become more confident as individuals, believers in the strength of teamwork and are well on their way to becoming excellent officers and leaders."

The Center does not shy away from seeking challenging, outside RPA research projects. Among these are a joint services project in cooperation with the US Naval Academy and the US Military Academy; while another joint project involves The State University of Pennsylvania and the Navy. Both proj-

ects are supported by the Office of the Assistant Secretary of Defense for Research and Engineering (DDR&E), Rapid Reaction Technology Office. The goal for both projects is for RPAs, unmanned ground vehicles, and sub-surface as well as surface naval vessels in various combinations to cooperatively provide protection of a sea and land area. During the 2011/2012 academic year, the Center successfully demonstrated these capabilities through actual RPA flight tests cooperating with unmanned ground vehicles and unmanned surface vessels and through simulations in the case of RPAs cooperating with the Penn State unmanned submarine and surface vehicles. Another cadet project sponsored by the Air Force Research Laboratory (AFRL) has autonomous RPAs cooperatively searching for, detecting, and locating radio frequency emitting ground equipment.

The Center's most important long-term research project is the continued development of autonomous cooperative technologies for heterogeneous unmanned vehicles to perform wide-area surveillance and reconnaissance using heterogeneous sensors



as well as to detect and track airborne chemicals. Enhanced capabilities for multiple RPAs to autonomously search, detect, validate with a second sensor technology, and localize a specifically defined building target were demonstrated this year in a project sponsored by the DDR&E Rapid Reaction Technology Office. Also demonstrated as part of the mission were the capabilities to maintain surveillance of the building and then concurrently track both a vehicular and human target using the appropriate sensor for each target.

To further enhance cadet learning, engineering mechanics cadets used a USAFA-developed suite of techniques to enhance innovation in the design



process to develop an innovative system using ducted fans to create thrust for a quad-rotor RPA that accomplishes ISR missions in caves and tunnels (funded by the Defense Threat Reduction Agency, Department of Homeland Security, and AFRL). Yet another cadet project using this suite of techniques developed a small fixed wing RPA to deploy a number of small sensor packages for covert, long duration ISR (supported by AFRL). "These types of projects push cadets to develop the ability to create innovative solutions to ill-defined problems," according to Dr. Dan Jensen in Engineering Mechanics, "a critical skill for these developing Air Force leaders."

Other cadet projects involve developing innovative airframe designs for future RPAs. Cadets are designing a very durable small RPA to support the future research platform needs of the Center. Another project involves refining their winning design of a fifth generation, low cost, stealthy, target drone for USAF use. Still another airframe design effort aims to provide a low cost, armed robotic wingman for manned aircraft. Dr. Pack has no doubt about the futures of cadets pursuing Air Force careers in RPA operations and unmanned technologies development. "It is clear from our experience in Iraq, Afghanistan, and elsewhere around the world that there is a bright future in the USAF for officers who understand the capabilities and employment of unmanned systems. Our efforts in the ACUASR help to prepare our faculty and cadets for this important responsibility before they leave the Academy."

AERONAUTICS RESEARCH CENTER

The Aeronautics Research Center (ARC) continues its tradition of involving cadets in all aspects of the research effort. A very strong program in aerodynamics, fluid dynamics, flight control and aircraft design continued throughout the year.

With the support of faculty, cadet research for NASA Johnson Space Center consisted of wind tunnel testing to define the aerodynamic characteristics of the Orion Multi Purpose Crew Vehicle drogue and pilot chutes.

“These efforts have contributed directly to NASA’s design and development of the Orion Parachute Recovery System used during re-entry of the vehicle. When cadets briefed the results of these efforts at the NASA JSC in June 2011, the reaction of NASA’s Chief of the Aerosciences and Flight Mechanics Branch was, “This is great work. It is critical to our design of the CEV Parachute Recovery System”, according to ARC Director Dr. Tom McLaughlin.

In addition, USAFA is undertaking testing to support development of a Flush Air Data System for the Orion. This will be a crucial system to provide angle of attack and sideslip information to the Orion after surviving the heating of re-entry.

McLaughlin has pioneered how research centers at USAFA incorporate research into the cadets’ educational experience, and if a project does not offer cadet research opportunities, McLaughlin said the center simply does not accept the project.

A continuing project with the South Korean Agency for Defense Development to control air vehicle forebodies at high angles of attack also evolved during the 2011-2012 AY. Dielectric barrier discharge plasma actuators, under development at USAFA for many years, have been incorporated onto a wind tunnel model to eliminate “roll-off” of the vehicle due to aerodynamic instabilities. Computer simulations support the experiments, with the intent of producing a closed-loop feedback system that will overcome this longstanding aerodynamic problem.

Complementing the strong aeronautics research, the ARC has initiated a push for equal strength in the propulsion field. Working closely with the Air Force Research Labs’ Propulsion Directorate, new initiatives seek to keep the USAFA effort on the forefront of propulsion technology.

The ARC opened a new frontier in gas turbine development with the development of the ejector, which entrains additional air into the engine and substantially improves fuel economy. Supported by the Chief Scientist of the AFRL Propulsion Directorate, USAFA engineers developed an analytic ejector/diffuser model for incompressible and compressible flow regimes that shows how the performance depends on the secondary to primary mass flow area ratio and the inlet to exit diffuser area ratio. To test the theory, an ejector/diffuser test stand was built. The test stand consists of a primary nozzle assembly driven by high pressure air with separate nozzle exit areas and an ejector/diffuser assembly with four diffuser exit areas. Students tested the apparatus and validated ejector performance in spring 2012. Future



plans include extending operation of the test stand to the supersonic flow regime and design and testing of ejector/diffusers that are embedded in airfoils for active flow control and thrust augmentation.

Arnold Engineering Development Center (AEDC) swirl generator testing on the F109 turbofan was conducted. This was to establish the Society of Automotive Engineers (SAE) S-16 dynamic distortion testing standards. Bulk Swirl and Twin Swirl generators of varying angularity were used to determine the aerodynamic and structural response. Fan maps, velocity triangle analysis, and Campbell diagram development using a non-intrusive stress measurement system (NSMS) data were developed for each case. A

team of independent study students reduced this data to develop an AIAA region V student paper. The effort was expanded in the Spring of 2012 to determine the effects of “spider” vanes on gas turbine fan blade vibration. This project provided the baseline data for future blade coatings as a mitigation technique for high cycle fatigue.

The USAFA Department of Aeronautics Aircraft Design Group (DFANADG) has been very active in its cadet research efforts. Most important of these was the 5th-Generation Aerial Target (5GAT), a large target drone being developed for the Office of the Secretary of Defense, Director, Operational Test and Evaluation (OSD/DOT&E). In 2011 DFANADG helped prepare 5GAT for preliminary design, an important step toward actual production of the drone. During 2011 OSD/DOT&E selected a DFANADG-generated configuration as the preferred system configuration for 5GAT. All future work on 5GAT will use this configuration. This is a first for DFANADG, having one of our designs selected for further development as a major US test and training asset.

DFANADG also developed several other aircraft designs. These included the Combat Aerodynamics Modular Prototype UAS (CAMPUS) and TuffFalcon. CAMPUS is a medium-size jet-powered aircraft being developed for aerodynamic research. When fully operational, it will be used as a research tool much like a wind tunnel to explore aerodynamics unique to stealthy combat aircraft. DFANADG cadets flew a half-scale model of the aircraft and made structural and systems improvements to the actual full-scale vehicle.

TuffFalcon is a small UAS intended to fly a variety of missions for a number of USAFA customers. Its name implies its salient feature – It is tough! This makes it suitable for rough use in training and research missions that repeatedly cause damage to the current UAS types used at USAFA. In 2011 DFANADG flew several candidate TuffFalcon configurations and selected one for further development.

ASTRONOMICAL RESEARCH GROUP & OBSERVATORY

USAFA's Astronomical Research Group and Observatory (ARGO) has a multi-faceted mission, directing all astronomy-related education for 300+ cadets across 7 academic courses annually.

“Cadet research at the USAFA Observatory develops future technical leaders who know how to apply the scientific method, as well as employ observational tools and techniques required of Air Force space scientists,” says Director of the ARGO, Dr. Devin Della-Rose. Under the guidance of Della-Rose, the ARGO directs an average of four cadet astronomy research projects each academic year, and facilitates all cadet research conducted by the Center for Space Situational Awareness Research (CSSAR).

In addition to its cadet-research and education mission, the ARGO plans and conducts all public outreach events at the USAFA Observatory for over 400 members of the Front Range Community annually.

Della-Rose said that while there is not a specific career field in the Air Force for astronomy, cadets and former graduates, who have conducted research for the ARGO, are more prepared for their careers as officers. “I recently received an e-mail from 2d Lt Samantha Howard, a Class of 2011 physics major, who now works for the Air Force Research Lab (AFRL) at Wright-Patterson AFB,” he said. “She wrote to tell me that she regularly employs the knowledge she gained from her observatory research experiences.”

One key research area in which 2d Lt Howard and eight other cadets have worked is the study of extra-solar planets, or “exoplanets” as they are usually called. Since the first published exoplanet observations in 1988, more than 760 exoplanets have been discovered, including 10 Earth-type planets where life could exist. Based on these numbers, our galaxy alone could harbor 10 million Earths, and our galaxy is just one of about 10 billion galaxies in the known Universe! It is therefore not surprising that ARGO cadet and faculty researchers are engaged in the investigation of new worlds.

Starting in Fall 2008, cadet researchers showed that USAFA Observatory telescopes could detect the miniscule drop in light as a known exoplanet passes between its star and Earth (called a transit). Data analysis techniques refined by Lt Howard, Lt Peter Tarvin, and C1C Grant Boehme have given ARGO the capability to monitor such transits with the same fidelity as world-class astronomical observatories.

Now, in early 2012, C1Cs Samantha Latch and Gordon Spahr are researching and analyzing groundbreaking results on the exoplanet Wasp-12b. A “hot Jupiter” orbiting a star about 871 light-years away, Wasp-12b is so close to its parent star (1/50th of the Earth-Sun distance) that its orbital period is only one Earth-day. This has made it ideal for cadet study, but also means it is literally being consumed by the Wasp-12 star. Thus the planet’s orbital speed and period are expected to change with time, and cadets Latch and Spahr are attempting to quantify this change (called transit timing variations, or TTVs). Such TTVs might also be due to gravitational tugs from unknown bodies in the Wasp-12 system. By combining the ARGO’s



results with those of researchers from the Nicolas Copernicus University in Toruń, Poland, cadets’ research will add to the body of knowledge on Wasp-12b. In parallel with this work, Dr. Della-Rose and C1C Boehme are now performing similar analyses on Wasp-3b and Wasp-10b transit data gathered during Dr. Della-Rose’s Fall 2011 research sabbatical. As with Wasp-12b, both these exoplanets are believed to exhibit TTVs, but more data are needed to understand each planet’s behavior.

“Our exoplanet work is clearly one of the highlights of ARGO research over the past three years,” said Dr. Della-Rose. “Making original contributions on these three exoplanets would solidify our standing in the professional research community and open doors for future international collaborations.”

Our solar system, galaxy, and universe are ever-changing, so impromptu research opportunities frequently present themselves. In September 2011, in the weeks following the discovery of supernova SN2011FE in the Pinwheel Galaxy, 21 million light-years away, a group of cadets led by C1C Gordon Spahr, successfully imaged SN2011FE with the Observatory’s 61-cm telescope to help determine its variation of brightness with time. This particular supernova was type IA, meaning that study of its light curve can help refine distance estimates to remote locations in our universe, and thus test cosmological theories of the universe’s evolution.

Another example of impromptu cadet-led ARGO research came in early November 2011, when the asteroid 2005 YU55 passed close to Earth, inside our Moon’s orbit. At over 300 kilometers across, this asteroid is classified as a hazardous near-Earth object, or NEO, meaning that a direct impact with Earth would be catastrophic. As with the Pinwheel Galaxy supernova, Dr. Della-Rose, C1C Spahr, and a group of cadets imaged YU55. Observing was difficult since a nearly full Moon was quite close to the asteroid’s line of sight. In spite of this, the ARGO observing team successfully imaged the asteroid and cadet-led analysis of the images produced orbital updates that will aid in future tracking of this asteroid. YU55 will pass close to Earth again in 2041.

As ARGO research continues to grow, future cadet and faculty researchers will be able to leverage the expanded coverage of CSSAR’s Falcon Telescope Network to surpass the limits of what we can see in the Colorado Springs night sky. Dr. Della-Rose concluded: “I’m very proud of the legacy of ARGO cadet, faculty, and civilian research that continues to build. It’s all been made possible by the unqualified support given to us and the USAFA Observatory by all levels of USAFA leadership.”

CADET SUMMER RESEARCH PROGRAM

The Cadet Summer Research Program (CSRP) is one the Academy’s longest running research success stories. Multi-disciplinary in nature, an average of 200 rising seniors every year participate in hands-on real world research programs across the nation in federal laboratories such as the Air Force Research Lab (AFRL), the Air Force Global Strike Command, Air Force Space Command and other military branches’ research programs, other universities such as the Massachusetts Institute of Technology, and in private sector companies such as Boston Scientific, Boeing and Intel Corporations.

The CSRP program supports the education and research mission of the Academy and offers cadets the opportunity to apply all they have learned from their time at USAFA to a real-world situation. Through Cooperative Research and Development Agreements (CRADAs), these research partners are able to get the best of both worlds- top notch research for reasonable investment. The Academy has nearly 80 active CRADAs that include not only CSRP

projects but also year-round projects within the labs that leverage the Academy’s equipment, faculty, and cadet resources.

Over the summer of 2012, cadets went to far-flung as well as close-to-home research programs.

Management major C1C Chris Kirk completed his five-week CSRP at SAF/AQ at the Pentagon working on budgeting and management challenges at the very upper levels of US Air Force leadership. In addition to getting kudos from USAF budget personnel, Cadet Kirk has also been recognized for his heroism. Kirk witnessed a horrific car accident, pulled over and saved one of the passengers in the vehicle, which had burst into flames.

The praise for the cadets’ 2012 efforts is immeasurable with both new and repeat customers praising cadets’ innovations, dedication, and professionalism. Several cadets’ had their work recognized as the best. C1C Yasmin Sarmiento’s work on ionic liquids as a forensics tool to identify explosive materials was

selected by the U.S. Army Criminal Investigation Laboratory as the DoD Project of the month.

“Though it’s not necessary appropriate to compare, he is very likely the best intern I’ve ever worked with. He’s smart, resourceful, motivated, intrinsically curious, organized, enthusiastic, articulate and makes an excellent argument. He sought out what he needed, critically evaluated it and synthesized a lovely vision of the compute continuum for us. But his “ace in the hole” is his listening skills. He *actually* listens carefully, attentively, openly and integrates actively what he’s hearing with what he knows. You can see it in his eyes...And then, for proof, he comes back with far more than what was asked of him—and it was always on target,” said Dr. Tony Salvador, Senior principal Engineer and Director of Intel Corporation’s Experience Insights Lab, of C1C Woody Go.

The cadets’ also come back with renewed energy and excitement. Many will continue the work they have started with CRADA partners as part of their senior capstone or independent study courses during their



senior year. Many CSRP participants also seek to continue their education and aggressively pursued and won recognized scholarships from top tier universities and medical schools.

“CSRP allows our cadets to apply what they’ve learned up through their junior year to real-world situations while contributing to the mission and gaining experience at other agencies. This provides the motivation and stimulation of their interests to continue research and contributes to their devotion to lifelong learning,” said USAFA Chief Scientist Col Bob Kraus.

CENTER FOR AIRCRAFT STRUCTURAL LIFE EXTENSION

According to the Air Force Times in 2010, the average age of aircraft in the Air Force is more than 24 years and some of the senior citizen aircraft such as the KC-135 tanker aircraft are today in excess of 50 years old. And the fleet is not getting any younger. This fact combined with the ever dwindling Air Force Inventory makes safe operation and maximum readiness of the remaining fleet critical to the warfighter.

To safely answer modern day readiness challenges, the researchers and cadets of the Academy's Center for Aircraft Structural Life Extension (CAStLE) work on the front lines of a full spectrum of material degradation issues and their impact on structural integrity. Led by Dr. Gregory Shoales (Director) and Dr. James Greer, Jr. (Technical Director), the CAStLE lab is a flurry of activity in its multi-million dollar laboratory which houses a diverse range of relevant test and fabrication equipment. CAStLE's newest technologies include a nano-laboratory for micro-machining and surface analysis, an advanced X-ray computed tomography machine,

two types of Electric Discharge Machines (EDM), a laser Computer Numerically Controlled (CNC) cutter, a rapid prototyper, and a coordinate measuring machine for reverse engineering.

The center is currently involved in projects ranging from new materials research, multiple aging aircraft structural teardown analysis programs, full-scale and component fatigue testing, validation of structural repair methodologies, corrosion characterization and modeling research, and energy harvesting projects. Funding for these efforts comes from a variety of sources including Air Force Air Logistics Centers, Air Force Office of Scientific Research (AFOSR) and other DoD organizations.

"CAStLE supports our cadets' education by giving them hands-on, real-world structural sustainment experiences. Many USAF aircraft are seeing their third generation of pilots—some of our cadets will be flying airplanes their grandfathers flew. They are seeing first-hand the breadth and depth of the technical problems that must be addressed to keep

these 'mature' aircraft flying for decades to come," said Greer. "Our cadets get to work with government and contractor teams charged with solving today's aircraft structural issues and, upon graduation, will head off to their Air Force jobs with a deeper appreciation of what's needed to sustain our warfighting capabilities."

Structural teardown analysis programs designed, planned and executed by CAStLE engineers with various aspects assisted by cadet projects, are used to destructively analyze retired USAF airframes to gain insight as to their condition not possible by any other means. Such insight in turn yields answers as to suitability of the entire fleet for extended safe service beyond original design service goals. Due to its previous record of successful research in this arena, CAStLE authored the USAF manual for Teardown Analysis Programs and is currently considered to be the world's expert on the subject. Cadet contributions, through their research projects, added to this important USAF manual and they have been duly credited for their contribution.



"Since the academic program of all department cadets includes key elements of one or more CAStLE projects, CAStLE is an integral part of the cadet curriculum. The center gets to cherry pick from each and every project to extract those elements best suited to create a meaningful cadet experience of applying S&T solutions to DoD operational issues," said Shoales. "Our cadets publish their work and present their successful solutions to DoD leadership." Cadets further benefit from project partnerships with graduate students and professors from the university partners of the Technical Corrosion Collaboration sponsored by the Office of the Secretary of Defense's Corrosion Policy and Oversight Office.

An example of on-going research conducted in the center can be seen in the C/KC-135 Teardown project, a partnership with Tinker AFB, involving three complete aircraft undergoing the most comprehensive nose-to-tail and wingtip-to-wingtip teardown analysis of any aircraft ever undertaken world-wide. Project researchers anticipate the inspection of more than 25,000 parts by multiple techniques from each aircraft. This program is expected to yield more than 30,000 inspection results per aircraft to help fleet managers reach the current service requirement beyond 2040. Cadets have been intimately involved in the evaluation of the fatigue residual life in fuselage lap joint panels, the evaluation of the static residual strength of similar fuselage lap joint panels, and real-life root cause analysis of the inspection indications. Multiple cadets have accomplished full analyses of inspection indications which have become part of the formal report and data used by the C/KC-135 fleet managers.

Another major thrust in the center's mission is its USAF Aircraft Structural Integrity Program Support. Due to the center's recognized structural integrity expertise, researchers and cadets provide continuous support to multiple aircraft fleet managers at Hill AFB (A-10 and T-38 aircraft), Tinker AFB (KC-135 tankers, B-1B bombers and TG-16A sailplanes), and Warner-Robins (C-130 transport and E-8C ISR aircraft). The projects are varied and range from designing and validating repairs, performing residual life analysis, performing structural condition assessments, augmenting the current crack growth prediction database, and exploring material substitutions of legacy alloys.

The 2010-2011 Academic Year also saw the completion of a six year project for the U.S. Coast Guard collecting critical flight data and analysis. This project not only resulted in cadet-developed temperature correction equations for a strain measurement device and the validation of CAStLE developed structural models, but also resulted in the safe extension of the life of the U.S. Coast Guard HC-130H fleet by several thousand flight hours.

"Our faculty's professional development is enhanced in much the same way, by providing them with state-of-the-art tools to address current sustainment problems for the Air Force. Working with other DoD professionals in the field, our faculty are able to bring the most current and relevant technical issues into the classroom. This obviously benefits the cadets, but also has a 're-bluing' effect on the faculty, fostering their professional development, and increasing their value to the cadets and the Air Force," added Greer.

CENTER FOR CHARACTER & LEADERSHIP DEVELOPMENT

The Center for Character & Leadership Development (CCLD) fosters the growth of character and leadership in the cadets and staff at the United States Air Force Academy through the many programs it facilitates. Its mission is to advance the understanding, practice, and integration of character and leadership development while preparing USAFA cadets for service to the nation in the profession of arms. The CCLD staff is committed to creating and shaping a culture at USAFA that celebrates this development and promotes its integration across the broader Air Force. The Center does this by providing world-class education and experiences for USAFA cadets and staff, enlightening and equipping future officers to advance lifelong habits of honorable living.

The 2011-2012 academic year was critical in the Center's advancement toward being the Air Force's "First Call" organization in matters of Character and Leadership. Principal among the activities was the development of CCLD's "Conceptual Framework" as a complement to the Academy's Officer Development System (ODS). This seven month initiative lev-

eraged a key group of scholars and practitioners from across USAFA mission partners to develop an accessible language and framework, grounded in research and best practices, to both describe and direct the appropriate actions of CCLD in a way that brings the ODS to life. This framework and its touchstone document further identified the fundamental elements of character and leadership development, and served as a "logic check" for CCLD programs, research, and initiatives.

Col Joseph Sanders, Permanent Professor and Director of CCLD, emphasizes that, "CCLD is committed to engaging in research that impacts both knowledge and application. Our conceptual framework drives and informs the research questions we ask and how we execute our 'theory of program.'"

The Conceptual Framework has already impacted research, assessment and programs within CCLD. For example, Center members delivered invited presentations and papers on the overall framework, its elements, and engaging CCLD interventions at

conferences for the Association of Leadership Educators (ALE), International Leadership Association (ILA), Association of American Colleges & Universities (AAC&U), New York University (NYU), and the Boeing Leadership Center. In addition, Lt Col Kevin Basik partnered with scholars at Cornell University to publish a chapter on developing Behavioral Integrity in the Emerald Group Publishing Limited edited book, *Management Education for Integrity Ethically Educating Tomorrow's Business Leaders*.

The center also oversaw the administration of the revised Honor Survey, which directly assessed the impact of multiple Honor Directorate initiatives purposefully focused on "living honorably," as opposed to a more litigious approach to honor education. The data has provided an important baseline for longitudinal analysis of program impact toward this important goal.

CCLD continued to extend its scholarly impact through the peer-reviewed *Journal of Character & Leadership Integration* (JCLI). This bi-annual publica-



tion showcases conceptual and empirical research from military and civilian scholars, as well as character and leadership practitioners. The online version includes several novel interactive features such as video and audio elements.

In addition, two new publication platforms were also introduced *Scholar Briefs* and *Character Connections*. The *Scholar Briefs* are stand-alone monographs on topics of relevance to targeted audiences, and are available in hard-copy and electronic formats. The first *Scholar Brief*, entitled "Return to Duty" was written by Lt Col Patrick Donley, a faculty member in the Academy's Department of Military Strategic Studies. This article challenged USAFA on its approach to developing a sense of duty among cadets. The

second *Scholar Brief*, by Department of Mathematics instructor Dr. Bradley Warner, presented a thoughtful perspective on how to teach character in technical classes.

Character Connections is a quarterly online e-publication that presents a compelling character and leadership based question, and then invites relevant contributors to respond in two- to three- page influence pieces. The publication includes a comment feature that generates interaction among the participating readers. The first issue's question, "Is Duty Dead?" was addressed by authors such as the Chairman of the Joint Chiefs of Staff (Gen Martin E. Dempsey) and the CCLD Senior Scholar (Dr. Arthur Schwartz). In the second issue, top consultants, educators and practitioners responded to the question, "How Do You Lead Those You Perceive to be Uncommitted?" All of these publications have reached broad audiences in the military, civilian academic and practitioner arenas.

Finally, CCLD conducted a very promising formal research project on character coaching. The "Character Mosaic" pilot study examined the impact of developmental coaching with volunteer cadets on the development of targeted virtues (i.e., those that align with the framework's definition of Honorable Living) that cadets selected after receiving a personalized report of their initial virtue ratings as identified by the Character Mosaic Instrument. This six month project with 55 cadets and their coaches produced impressive empirical results indicating a significantly better improvement in virtue scores and fewer institutional infractions for those who participated versus those who did not. The results of this quasi-experimental study have significant implications for character and leadership development at the Academy. Cadet feedback on the pilot program has been consistently encouraging. As one cadet participant said, "Overall, this program helped me look at how I live my life more in-depth and gave me guidelines on how to improve my virtues."

The CCLD with its many goals for its programs, events, and scholarship expansion is always striving for innovative instruction and research into the disciplines of character and leadership, to continuously learn and adjust to the demands of change, and to challenge established worldviews about character and leadership.

CENTER FOR PHYSICS EDUCATION RESEARCH

Providing a platform on which faculty and students can become fully engaged in physics, physics education, and Science Technology Engineering and Mathematics (STEM) endeavors, the Academy's Center for Physics Education Research (CPER) is on the frontline of transforming the Academy's learning and teaching environment. Housed in the Department of Physics and led by Lt Col Steven Novotny and Distinguished Scholar Dr. Gregor Novak, the center spearheads multiple research efforts with the goal of improving STEM education in USAFA classrooms and nationwide.

"When trying to assess the efficacy of any pedagogical strategy, it is important to appreciate that the choice and implementation of a particular teaching method will affect student and faculty attitudes and motivation as well as learning outcomes" said Dr. Gregor Novak.

Building upon the success of its internationally recognized flagship project, Just In Time Teaching

(JiTT) and JiTT's extension through the center's Worked-Examples pedagogy, CPER has focused efforts on creating research-based materials to enable any school and any instructor to take advantage of USAFA-proven techniques. CPER has developed a pilot version of a pedagogical approach using pre-instruction learning objects and featuring an expert's treatment of a short problem task for the learner to deconstruct and analyze. This "Worked-Examples" approach, implemented as the foundation for all core physics courses, has been tested on over 3,000 students, with encouraging results and wide-reaching impacts.

The CPER's goal is to impact USAFA and the nation's STEM education by further developing a library of research-based materials that will aid instructors in providing the proven benefits of an active learning environment. The CPER is beginning the task of developing 200 pre-instruction learning modules, classroom-testing the materials, and disseminating the materials nationwide through a digital library funded by the National Science Foundation (NSF).

CPER research is looking beyond classroom instruction and directly into the minds of the students. Cognitive science and education research suggest learning that incorporates metacognitive knowledge and skills leads to longer lasting outcomes. The research also suggests that metacognitive skills can be acquired with curricula that help students develop an awareness of their inquiry process and the ability to reflect on what they are doing. Such curricula better meet the needs of "millennial" students. CPER researchers are using the results of existing metacognition research to formulate curricula to improve and strengthen student inquiry skills.

All of these efforts produce future Air Force officers possessing better critical thinking skills in technical and non-technical problem solving. Instead of leaving their physics courses with a handful of memorized equations, they will leave better able to attack any intellectual problem. "With a concept-oriented approach to a concept-oriented science, the equations became the tools they are supposed to be instead of the solutions to a test." [anonymous Cadet Third Class]



Based upon software developed by a multi-university group, the CPER is creating and evaluating computer-modeling exercises for an introductory physics course that will develop students' metacognitive knowledge and skills. Students will be guided in the construction and testing of models to represent physical scenarios. Supported by video-game quality simulations, students will practice hands-on implementation of the scientific method, begin to understand how science develops laws of nature, and acquire a more permanent understanding of the physics content through a guided-inquiry process. It is important to help students see that "incorrect" answers are not evidence of failure on their part but are stepping stones in the learning process. Prototype modules are currently being tested by several hundred cadets in USAFA's introductory mechanics course.



CPER research efforts are also looking to exploit the capabilities of mobile technology to address a classroom issue: improving the frequency and quality of in-class student engagement. The center's goal is to elevate the frequency and quality of meaningful classroom engagement in physics core classes. The CPER is developing a mobile technology based system for monitoring student participation in all classroom activities on a daily basis and providing real-time scoring data to instructors through a mobile device such as an iPad™, iPod Touch™ or Android™-based device. Students will be rewarded for showing evidence of classroom engagement. The system will consist of a server and in-class mobile devices with which instructors will assign credit and monitor participation throughout the semester. The data will be fed back to the mobile devices to inform the instructor about the level and recency of participation by the students. The data will also be analyzed and compared to other metrics such as test results and student surveys to improve the design of the pre-class assignments and the in-class activities. Forty cadets are currently involved in a study of this engagement technique and gains are already being seen over similar control groups.

"For the first time, we are seeing a quantified link between particular classroom activities and performance on graded assessments. The observed links highlight the importance of quality engagement and provides hints as to which types of engagement contribute to deeper conceptual learning" said Lt Col Steven Novotny.

CENTER FOR SPACE SITUATIONAL AWARENESS RESEARCH

The space environment around Earth has become increasingly congested, contested, and competitive as more nations develop and launch satellites for civil and military purposes. Consequently, space situational awareness (SSA) is a vital component of U.S. national security and is foundational to our country's success in operating safely and freely in space.

The Department of Physics Center for Space Situational Awareness Research (CSSAR), led by Dr. Francis Chun, is providing cadets and faculty with world-class capabilities and facilities to conduct cutting-edge SSA research. This past year, CSSAR garnered recognition from the space community for providing unique capability and opportunities for satellite characterization research. Indeed, Dr. J. Douglas Beason, the Chief Scientist of Air Force Space Command, stated that CSSAR "has made great strides in developing a cadet education and research program in space situational awareness."

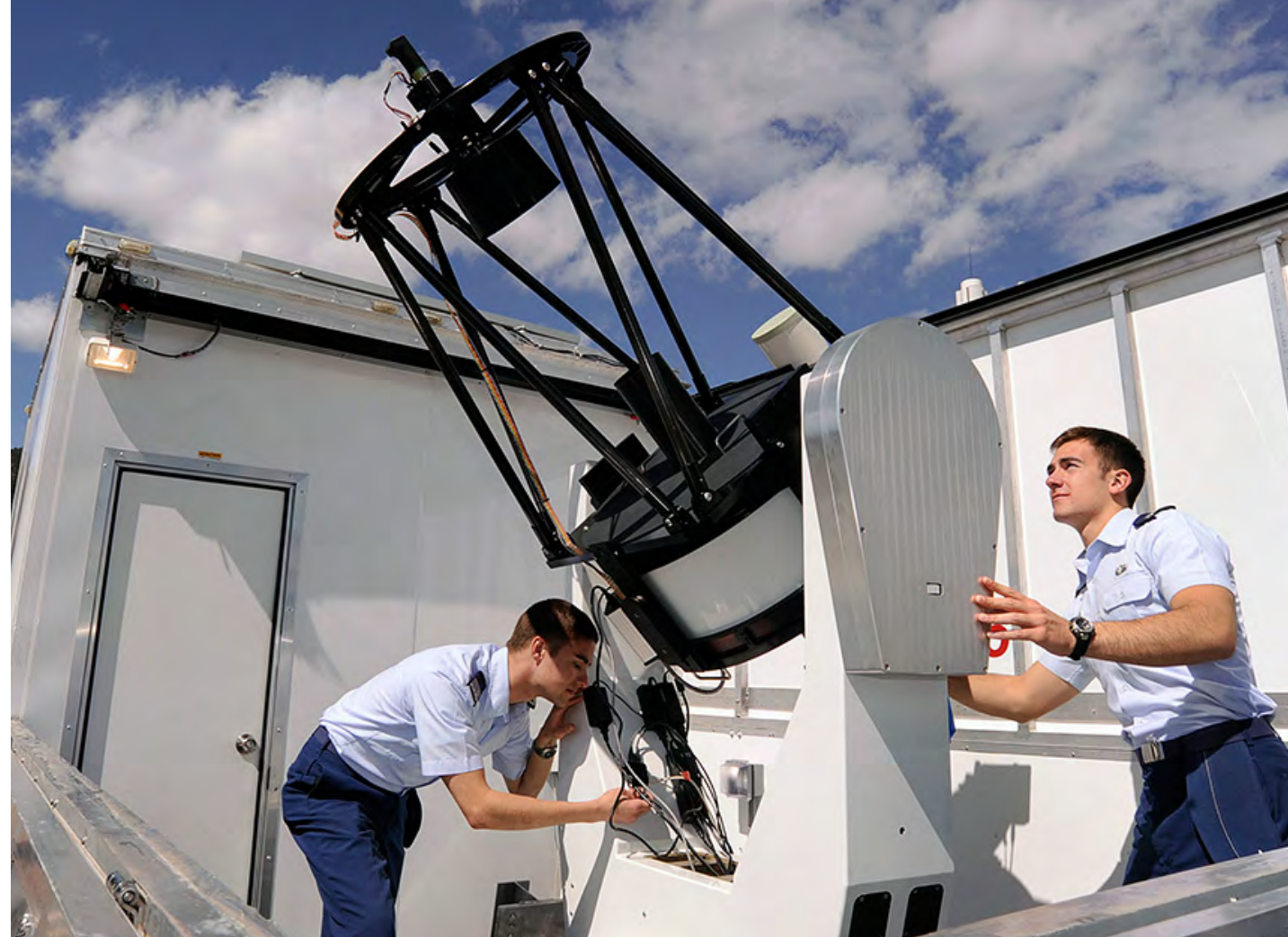
In Fall 2011, Drs. Chun, Roger Tippets, and Michael Dearborn of CSSAR were awarded a \$791,500

grant from the Air Force Office of Scientific Research under the Defense University Research Instrumentation Program to develop a global network of small aperture optical telescopes for non-resolvable space object identification called the Falcon Telescope Network (FTN). Along with an additional \$1,000,000 from the Academy, CSSAR is partnering with educational institutions around the world to build an initial FTN of 12 fixed telescope observatories and 2 mobile observatories. Six of the fixed sites will be in the state of Colorado to include Colorado Mesa University in Grand Junction, Fort Lewis College in Durango, Northeastern Junior College in Sterling, and Otero Junior College in La Junta. An additional two Colorado sites are co-located at the Academy and at the Farish Recreation Area just west of the Academy. The remaining U.S. sites for the FTN include Penn State University and the U.S. Military Academy (West Point). The overseas sites include Chile and Australia, with a potential location in South Africa. According to Dr. Beason, the FTN "offers the space community a low-cost, high-payoff approach for pushing the state-of-the-art in satellite characterization and predictive

assessment." This past year, cadets have been active in the center's SSA research. C1Cs Shannon Young and Stephen Wakefield conducted research on geosynchronous satellite spectral signatures using a slit-less spectroscopy technique. Young and Wakefield have been successful in developing a robust process for calibrating the satellite spectral signatures by taking into account camera pixel sensitivity and solar-type features.

C1Cs Eli Garduño and Joe Silverio measured the photometric signatures of space debris as a function of time in order to characterize their spin rate and spin axis orientation in support of the NASA Active Debris Removal Program. Garduño and Silverio identified some very interesting tumble behavior for some of the space debris objects. In Spring 2012, Garduño and Silverio undertook the project of analyzing these and other light curves using Fourier techniques to identify their primary period and spin axis orientation.

C1C Kody Wilson conducted research to analyze and determine the optimal location of multiple telescopes



relative to a satellite pass in order to increase the success rate of a satellite shape determination algorithm previously developed by Lt Dan Fulcoly (USAFA Class of 2010). Wilson presented his initial results at the AFRL Non-Resolvable Space Object Identification Workshop in Maui, Hawaii in September 2011 where he showed the improvement of the algorithm when data from more telescope sites were combined. This result confirmed and demonstrated, for the first time, the validity of the CSSAR's premise that observation of satellites simultaneously from multiple telescopes is inherently better than from a single telescope. C2C Brandon Mueller joined the team to create an FTN computer model that will help determine various observational scenarios and produce simulated data to compare to real-world

observations

All these cadets recently presented their research results at an Air Force Research Laboratory workshop on non-resolvable space object identification techniques. "This was an excellent opportunity for our cadets to showcase their research in an informal setting to an audience of internationally renowned experts in satellite characterization," said Chun. "It was also an opportunity for our colleagues in the SSA research community to interact with our cadets and to witness firsthand the Academy's strong commitment to not only graduating officers of character, but also officers with a strong understanding of the space domain. Many of them expressed support and admiration for what we are doing in the education of our future Air Force leaders."

CSSAR continues to garner support and interest from the Department of Defense and the Air Force, especially in the development of the FTN and the Cadet Space Operations Center (CSOC). With help from the Electronic Systems Center and MITRE, CSSAR installed the first instantiation of the CSOC in the Observatory classroom. Using government software and MITRE hardware, Dr. Dearborn has created the ability to visualize any satellite orbit in the space catalog and show the optical coverage of the FTN. Ultimately, the CSOC will be the command and control center for CSSAR sensors (like the FTN), fusing sensor data with other data sources and will allow cadets and faculty to maintain a small catalog of space objects for space situational awareness.

In short, CSSAR's development of the cadet education and research program in SSA is paying dividends to the Air Force. Recently, Lt. Fulcoly visited some space surveillance radars in the New England area and remarked that the SSA course at USAFA "left me more than qualified to converse intelligently with the staff at both facilities, sometimes even asking questions that were beyond their knowledge!" In the end, as Dr. Beason says, CSSAR "will help us accomplish one of Air Force Space Command's long-term science and technology challenges: 'Provide real-time, predictive, cross-domain, assured situational awareness.'"

CHEMISTRY RESEARCH CENTER

The Chemistry Research Center (CRC) at the United States Air Force Academy has continuously evolved since its inception in 1995. For 33 years prior, the Frank J. Seiler Research Lab operated alongside the Chemistry Department, impacting, impacting and shaping thousands of cadets. Dr. John Wilkes, the director of the CRC for nearly 25 years, has been the inspiration and guiding hand to hundreds of faculty members and thousands of cadets.

Known as the father of ionic liquids, Wilkes has established the center as one of the top Chemistry Research facilities in undergraduate institutions nationally. The center houses approximately \$4.5 million worth of research equipment and instrumentation. A secret to their success comes from collaboration with partners such as the Air Force Research Laboratory, Lawrence Livermore National Laboratory, Los Alamos National Laboratory, the US Army Criminal Investigation Laboratory, and the Air Force Office of Scientific Research. The CRC currently has several thrusts of focused research including ionic liquids, forensics, and nanomaterials research.

“Ionic liquids can be designed by chemists to dissolve just about anything, sort of like medicinal chemists can design pharmaceuticals that affect your body and mind in specific ways,” said Wilkes. “World-wide interest ranges from pure basic research on the synthesis and properties of new ionic liquids at universities to application of now commercially available ionic liquids to industrial chemical processes.” Wilkes has seen hundreds of uses for ionic liquids emerge during the course of his career. The research center has offered cadets at the Academy excellent opportunities to discover new uses and applications for ionic liquids.

Some of the more recent efforts and discoveries include the discovery of a new thermal heat transfer ionic fluid, application of ionic fluids in chemical warfare agent neutralization, and illicit drug detection and analysis. Known as Chemical Biological Radiological Nuclear Explosive or CBRNE, research into this arena is a national defense priority. Under a three-year research project with the US Army Criminal Investigation Laboratory (USACIL), research-

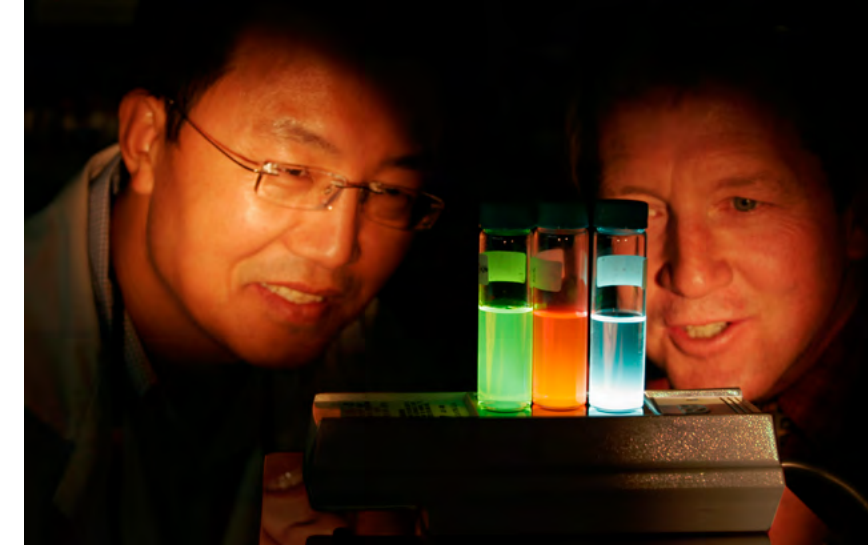
ers and cadets have been looking for new ways to detect, identify and neutralize CBRNE agents in the lab for both national security purposes, as well as criminal forensics applications where CBRNE or illicit drug use, such as methamphetamine, is suspected. In 2012 Cadet Michelle Kiyota conducted USACIL research on which type of ionic liquid is most suitable and stable for detection of TNT residue. She identified the best type of polymer swab technology for the transfer of the substance from a surface to the ionic liquid and determined if the ionic liquids used were able to preserve the evidence of TNT residue.

This ability would be important to law enforcement agents who would need to also preserve the evidence discovered by any future applications of this technology. Kiyota successfully showed through her research that samples could indeed be preserved for 55 days or longer after sample collection. This research project was continued by Cadet Yasmin Sarmiento during the 2012 Cadet Summer Research Program at USACIL researching a one swab solution for all



types of forensics samples, improving storage capabilities, and utilizing a faster analysis method.

“Instead of just seeing chemistry in the classroom, I saw our research being applied to real world forensic investigations and applications,” said Sarmiento of her research, which she and her fellow research partners are working to publish. “I had a close up view of how research is applied in the broader Air Force.” Sarmiento hopes to apply what she has learned in her career as an officer and said her work in forensic chemistry can be applied to many jobs in the Air Force including the Office of Special Investigations, research acquisitions, or in law.



In the recent past, researchers in the CRC have contributed to discoveries on the ability of ionic liquids to dissolve simulants of nerve agents and biological agents, with funding provided by the Defense Threat Reduction Agency. Now this research team, comprised of Wilkes, faculty, research contractors and cadets have made considerable discoveries including proving immediate success in applying ionic liquids in the collection, retention and analysis of explosives and drugs. Utilizing a type of ionic liquid known as 1-ethyl-3-methylimidazolium tetrafluoroborate to identify the explosive 2,4,6-trinitrotoluene (TNT), USAFA Researcher Hannah Miller successfully developed a qualitative color screening test for the presence of TNT, which is the most common component of military explosives. Further experiments have demonstrated that the amount of TNT collected could be quantitated by liquid chromatography coupled to a mass spectrometer. In her research she observed that as soon as the colorless TNT dissolved in the colorless ionic liquid, the homogeneous solution was turned a deep red in color. Other nitro- compounds dissolved, but did not show the red color.

“The Chemistry Department, under the leadership of Dr. Wilkes, has a long-standing tradition of premier cadet research I plan to continue this tradition by equipping our chemistry majors with the tools they need in order to meet demands of the operational Air Force as future officers,” said Dr. Scott Iacono, who took over leadership of the center upon Wilkes’ retirement in summer of 2012. “Cadet research goes beyond the grind of mixing chemicals to come up with the next big thing, rather it is seeing a cadet’s progression of becoming independent thinkers which is truly what makes them critically thinking leaders.”

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

Infrastructure is a critical part of our nation's ability to respond to natural or man-made-disasters. Efforts to make our infrastructure more energy-efficient, safer, and less costly is one of the main missions of research efforts in the Academy's Department of Civil and Environmental Engineering (DFCE). DFCE research efforts focus on four subject areas: infrastructure protection, environmental engineering, energy conservation and sustainable buildings, and engineering education. Cadets are research partners in technical subject areas, assist with conducting the research, and publish their efforts with faculty mentors.

"DFCE research motivation is based on the development of cadets as lifelong learners, and the support of the Air Force, the Department of Defense, and the nation," said DFCE Department Head Colonel Gregory Seely.

One example of this from the 2011-2012 AY, C1C Casey Hableutzel used the American Society of Civil Engineers national Infrastructure Report Card as a

template to analyze the resiliency of the Colorado Springs' area stormwater, drinking water, waste water, bridge, road and transit infrastructure systems. Hableutzel presented the results of the study at the 2012 Critical Infrastructure Symposium and the resiliency grades for each of the six infrastructure systems will also be included in 2012 ASCE's Colorado Springs Area Infrastructure Report Card.

DFCE faculty Lt Col John Christ led a project sponsored by Strategic Environmental Research and Development Program (SERDP) on the protocol development for characterizing dense non-aqueous phase liquid (DNAPL) source zone architecture and associated plume response. DNAPL is considered a significant contaminant. Environmental engineering research efforts also focused on indoor air quality both for newly constructed residential housing and for our deployed troops housed in units constructed of particle board.

The DoD's Environmental Security Technology Certification Program (ESTCP) sponsored an en-

ergy foundation project related to construction of an energy foundation system and associated monitoring equipment in a shower/shave facility constructed at DFCE's Field Engineering Readiness Laboratory (FERL) site in 2012. Energy foundations combine the structural supports for a building with a ground source heat pump to provide a highly efficient heat source and sink. The DoD hopes to take advantage of this technology as part of making energy more secure and reliable. The project is part of an on-going partnership with the University of Colorado-Boulder and will also supply data to the National Renewable Energy Laboratory. Research on this project includes long-term monitoring of the system's performance with respect to energy and fuel use, as well as a comparison of measured performance indicators including construction and life-cycle costs with those expected for conventional building heating and cooling systems. Cadet independent study and summer research projects will continue into the future to analyze the energy and carbon emission savings associated with energy foundations.



Engineering education research is blossoming in the department. DFCE has partnered with the Academy's Scholarship of Teaching and Learning (SoTL) on joint projects exploring the benefits of service and field learning, influence of learning contracts on student commitment and academic performance.

DFCE cadets work with mentors to construct two Navajo Hogan-style homes, which are then donated to the Navajo Nation. The wood frame construction activity offered during FERL continues to be an annual project and is being used to evaluate the importance of service and field learning activities in an engineering curriculum. Some of the elements assessed

include the importance of service and experiential learning on cadet cultural awareness and performance in subsequent engineering classes. Other variables researched include changes in students' perception toward service learning and community involvement. The importance of this field learning activity to contextualize and enrich engineering experience, which is believed to be needed to succeed during subsequent classroom instruction, was also examined.

The department also began a cooperative research project with the Department of Foreign Languages on exploring the effectiveness of multi-disciplined instruction and research on learning.

The faculty team developed a course entitled Cultural Consciousness and Humanitarian Support, in which cadets designed and constructed a prototype sand filter to purify drinking water for African nations. The impact of multi-disciplined instruction on student learning as well as instructors' perceptions of challenges and successes was documented. The results of this research will be used to determine if multi-discipline instruction was beneficial and if the service learning portion of the course was effective.

Specific topics addressed in the course included exploration of the following questions: What are some of the characteristics of the way of life for Africans? How did Africa get the way it is today? How has aid affected Africa? Can charity aid be employed effectively? The students taking this course solved a real humanitarian problem in a developing country through a hands-on service project and the proper application of cultural awareness, engineering technology, and community partnerships.

"This multi-disciplinary course gives cadets the chance to learn technical and cultural material in a context of a real humanitarian problem—that they help solve," comments Col Seely. DFCE is especially proud of this course and associated research as it promotes the kind of well-rounded learning and character development that we seek in future Air Force officers.

Col Seely summarizes, "All our department research efforts help the cadets learn how their education fits in solving complex problems locally and around the world and is a tremendous force multiplier for cadet education."

DIVISION OF HUMANITIES

Bertolt Brecht, a German poet, playwright, and theater director, once said, “Art and science coincide insofar as both aim to improve the lives of men and women.” From Philosophy and English to Aeronautics and Computer Engineering, the Academy’s dedicated instructors aim to positively impact the lives of cadets, who will become the leaders of the future. At this institution, cadets take the road less traveled, graduating with a synthesis of science and the humanities. At USAFA, the Humanities Division consists of English and Fine Arts, Foreign Languages, History, Military and Strategic Studies, and Philosophy, and each of these departments is making key strides in research, while developing and educating the leaders of tomorrow.

The Humanities Division encourages collaboration across disciplines and cultures as well as between faculty and cadets. One example of this is in the English and Fine Arts division where Dr. Pam Aloisa helped cadets learn from Carl Bartecchi through his work displayed in the Permanent Professors Art Gallery. Bartecchi was a photographer, physician, and

former medical officer during the Vietnam War, and cadets were able to see the significance of medical work in military environments—within the context of the human lives that are shaped by such service. Cadets also studied other cultures and presented internationally, through the Foreign Languages Department. Faculty and cadets in this department offered research presentations in Brazil, Puerto Rico, Costa Rica, Peru, Zambia, and Ghana. Inspired by Dr. Ismênia Sales de Souza’s mentorship and leadership, three cadets presented a research paper at the IX Congreso Internacional de Literatura Hispánica while one cadet participated in XI Congreso Internacional de Literatura Hispánica in Peru. The work of these young researchers was well-received and met with critical acclaim.

To broaden cadets’ educational foundation and further encourage integration and collaboration, the divisions sent cadets on both foreign and domestic Cadet Summer Research Projects (CSRP). Through the CSRP program, three cadets from the history department interned with the National Security

Agency (NSA) in order to engage in classified historical research regarding NSA programs. These cadets were able to integrate the art of history and humanities research with the science behind the NSA. Another history cadet, Nathaniel Shanks, went to the Air Force Space and Missile Systems Center (SMC) at Los Angeles Air Force Base where he researched and wrote a ten-page history study, comparing and contrasting the Air Force Acquisition Reform initiative of the 1990’s and the Department of Defense Acquisition efficiency initiative of the present. In reviewing Shanks’ work, the Chief of the SMC History Office explained that Cadet Shanks’ study was “an excellent analysis of the causes, characteristics, and impacts of the two most important military acquisition themes of the last twenty years.”

Separately the Department of English and Fine Arts sent Cadet Adam Evenson to the Southern Office of Aerospace Research and Development in Santiago, Chile where he worked on several technical writing projects. While in Chile, Evenson worked with the US Embassy and members of the Chilean Air Force



to draft technical documents that are being used in finalizing a satellite agreement for the southern hemisphere. Due to his exceptional work on this project, Cadet Evenson was Humanities Division nominee for the Moore Award, given each year for one outstanding cadet summer research project.

Adding to the diversity of research projects across the Humanities Division, Cadets Kaitlyn Bogan and Joanna Pattugalan, from the English and Fine Arts Department, studied senior leadership communications and social networking at Los Angeles Air Force Base. Cadets Bogan and Pattugalan jumped in head first to better understand communication avenues



and techniques available to them as young officers in a technologically advanced Air Force. As methods and technologies in communication change, it is imperative that cadets understand how to use these tools purposefully and strategically. Taking yet another research avenue, Cadet Alex Nelson participated in a business writing project at the Darden School of Business at the University of Virginia. Nelson reflected on her experiences there, saying, “My time at the Darden Business School at the University of Virginia taught me how valuable a degree in English is. This was not an internship where I made copies and got coffee. I wrote real case studies and technical data reports that will be used in Darden curriculum. It was a great educational experience.”

Cadet research in the Humanities Division is about first-hand experiences and exploration of the subjects and practices associated with the discipline. These experiences and explorations are driven by a desire to learn about the endeavors humans undertake and the conditions under which they pursue them. Research in the Humanities always has a mind toward cultures, people, and ideas and how those differences enhance both personal and professional growth as an individual and a leader.

DIVISION OF SOCIAL SCIENCES

Since research is a critical component of every cadet's experience at the U.S. Air Force Academy, the Social Sciences Division strives to challenge cadets to maximize their learning through wide-ranging human subject and other research opportunities. Whether in Behavioral Sciences and Leadership, Economics and Geosciences, Law, Management, or Political Science, cadets are engaging in research both in the classroom and across the nation and world.

The multi-disciplinary USAFA Cadet Summer Research Program (CSRP) offers cadets unique opportunities to apply their knowledge to real-world situations—in essence a “laboratory application” of the ideas learned in the classroom. Over the summer, cadets from the Social Sciences Division conducted research with the Air Force Research Laboratory, Boston Scientific, the Air Force Operational Test and Evaluation Center, the Space and Air Warfare Command, the Air Force General Counsel's Office, the Colorado School for the Deaf and the Blind, and many other organizations.

The Department of Political Science sent C1C Julian Gluck and C1C Jay Ziegler to serve as congressional interns for Senator Scott Brown (Massachusetts) and Senator Michael Bennett (Colorado), respectively. Both cadets then completed independent studies on the role of providing constituent services. A third Political Science major, C1C Fumiko Hedlund, anticipates presenting her research on political development in Afghanistan to U.S. forces in Kabul advising the Afghan government.

According to Hedlund, “The successful recovery and improvement of the country depends on the Afghan government's ability to effectively utilize and distribute the revenue it generates and the aid it receives. If the Afghan government cannot employ revenue and aid to support the Afghan people's welfare and supply adequate security, the country will not stabilize, and the government will lack both capability and permanency.”

Legal Studies major C1C Dayna Grant traveled to Monrovia, Liberia, to do research on land tenure

issues in distressed Liberian neighborhoods. She interviewed numerous Liberian leaders and citizens and researched Liberian and comparative law in developing a comprehensive recommendation for dealing with squatters' rights. Her research will be published as part of a five-year project funded by the West Point Center for the Rule of Law. C1C David Robinson and C1C David Shadoin, also Legal Studies majors, were co-researchers in a joint program at the U.S. Army Criminal Investigations Laboratory in Georgia, conducting extensive research on the impact that gunshot residue testing had on investigations and legal proceedings.

In addition to these hands-on experiences outside the classroom, cadets in the Department of Behavioral Sciences and Leadership also made a strong showing at the Eighth Annual Colorado Springs Undergraduate Research Forum (CSURF). Cadets participating in this forum presented a broad range of research including: Designing the Helmet Mounted Display for the U.S. Army Future Combat System, The Effects of Driving Glasses on Driver



Performance, Study of Multimodal Oxygen Monitoring in Firefighting Scenarios, and Color-Coding Strategies for Control Displays of Multiple Remotely Piloted Aircraft.

The Department of Economics and Geosciences is engaged in a wide variety of research topics, reflecting the diverse academic specialties of its faculty. Economic research has focused on the econometric analysis of the effectiveness of the Air Force Foreign Language Bonus Program, econometric analysis of the ability of Academy variables to predict future Air Force career success, and experimental economic analysis of mechanisms to allocate public goods and behavior in non-market valuation surveys.



Other research in economics addresses the relationship between the European “Church Tax” and church attendance. In the Geosciences, research agendas include the Hispanization of American culture, Critical Geopolitics, Cryopolitics, remote sensing of desert vegetation, cosmogenic dating of alluvial fan surfaces, chemical weathering of basaltic minerals, and patterns of crime and policing in support of the Colorado Springs Police Department. When feasible, the department also engages cadets in research efforts, to include participation in cross-departmental research such as an on-going collaborative effort with the Department of Biology to assess the risk of infectious diseases in America's National Parks.

The Department of Management maintains a significant research portfolio and promotes intellectual collaboration between faculty members and cadets. An example of their success with cadet-oriented research is C1C Colby Chaput's work on logistics planning with Walmart, which won the USAFA-wide cadet summer research award. Another example is the Technology Innovation course project team's efforts on a business plan for Exogrip, an exoskeleton hand-therapy device developed with cadets and faculty in the engineering division. The Exogrip team won first place in the University of Texas-El Paso's Camino Real venturing competition.

In summary, the faculty and cadets of the Social Sciences Division continue to aggressively pursue research opportunities that result in better learning for students, increased faculty development and scholarship, and solutions to real-world problems for our Air Force and the nation.

EISENHOWER CENTER FOR SPACE & DEFENSE STUDIES

The Eisenhower Center for Space and Defense Studies is the research center for the Department of Political Science, providing a focus for faculty and cadets in the field of defense and security studies, which has been a tradition in the Department for fifty years. The Center works to create opportunities to bring cadets and faculty members together with policy makers and contribute new ideas to improve the understanding and analysis of emerging challenges in the 21st Century. Through first-hand exposure to national and international leaders in workshops and discussions organized by the Eisenhower Center, cadets learn directly from leading experts about the issues and problems that will confront them in their Air Force careers. In particular, the Center engages cadets who are neither from engineering or science degree programs nor destined for assignment in the space and missile career field. In so doing, the Eisenhower Center increases the number of Academy graduates with a greater depth of understanding of the security and policy issues in the space and cyber domains and how these play in overall U.S. defense and strategic policy, contributing not only to enhanc-

ing military capability but also to achieving overall U.S. foreign and strategic policy goals.

Led by Ambassador Roger Harrison, over the past seven years the Eisenhower Center has greatly increased the resources the Academy devotes to space and security studies, including the publication of its Space Defense Policy textbook, expansion of graduate study opportunities in space policy for cadets, funding cadet and faculty research projects and internships, and bringing cadets together with senior officials and other experts in workshops on key space policy issues facing the United States. These workshops have included a series of discussions on topics ranging from improving space situational awareness, the dynamics of US-Chinese strategy and security in space, and trans-Atlantic space cooperation.

In 2012 the Eisenhower Center begins its first year of research under the Minerva Initiative, sponsored through a grant from the Office of the Secretary of Defense. Through the Minerva research grant, the Center will host two civilian guest researchers who

will pursue their individual research projects examining internal and external developments shaping the strategic relationship between the United States and China. The Minerva Fellows will also provide a means to renew research partnerships in the social sciences between the Department of Defense and civilian universities.

The Center is named in honor of Dwight D. Eisenhower. Eisenhower was the first American president to establish a national policy on the use of space for both military and civilian purposes. His legacy—the creation of both the National Reconnaissance Office and NASA—laid the foundation for the manned space program, the use of space to bolster national security, and the infrastructure which led to revolutions in battle management and global communications. This foundation remains the benchmark against which all successive policies are measured.

“When we think about space, we tend to think about it technically. We need to think about it politically and strategically. The space domain confronts the war fighter with distinct challenges, both operationally and in terms of policy. The Center’s task is to prepare Air Force Academy cadets for those challenges, giving them the opportunity for cutting edge research and to nurture them as future leaders of the greatest aero-space force in the world,” said Harrison.



HUMAN PERFORMANCE LABORATORY



The Human Performance Lab (HPL) at USAFA has been involved with altitude acclimatization research since Lt Col Michael Brothers' initial retrospective and cross-sectional investigations in 2011 and 2010. These investigations plus a subsequent longitudinal study provided the foundation for cadet research opportunities. The findings from these studies provided valuable insight on how one acclimatizes to altitude coming from a sea level residence. Generally it was found that physiological adaptations took longer than previously thought. The human performance lab has continued investigating acclimatization research questions with recent studies looking at the effects of a short-term loss in altitude on one's physiology such as that experienced over winter break. Specifically, these studies have focused on changes in total hemoglobin mass pre vs. post winter break. The loss in hemoglobin mass, which averages 4–6%, is significant and can affect performance on the aerobic fitness test (AFT—1.5 mile run) post winter break if one has not reacclimated to altitude.

The study conducted during AY 2011-2012 was designed to continue previous research from AY 2010-2011 for the purposes of increasing statistical power. This study was led by Lt Col David Welge, an assistant professor in the biology department. This collaborative effort provided C1C Elvira Chiccarelli, C1C Zach Schneider, and C1C Lane Thaut an opportunity to obtain research experience and understand the processes and diligence of effort required to achieve statements of research findings. C1C Chiccarelli previously won 1st place for the John C. Johnson Award for Excellence in Student Research for presenting initial acclimatization findings from the AY 2010-2011 study (Poster Presentation at the 2011 Tri-Beta regional undergraduate conference). The recent study sought to investigate the effect of a temporary sea level sojourn of ~14 days (winter break) on total hemoglobin mass, running economy, lactate, and oxygen saturation and how these variables acclimatized two months post winter break. Specifically, the investigators sought to determine if significant differences existed between cadet class years or whether years of residence at altitude had an effect on person's ability

to return to baseline values post winter break. Additionally, the effects of a chronic exercise regimen (athletic status) and gender were also assessed as to their effect on acclimatization.

“Providing opportunities for cadet research is very important to the USAFA mission. Research experience can provide cadets with valuable insight into what is involved in the research process such as preparation, understanding and implementing methodology, data analysis, and presentation of results,” said HPL assistant professor Dr. Jeff Nelson. “What goes into a final product, such as a manuscript, abstract, or poster presentation, is often the result of long hours of hard work. Additionally, cadets appreciate that attention to detail in the research process has a direct correlation to the quality of the results.”

The findings of ongoing altitude acclimatization HPL research has a direct application to DoD and AF missions in theatre. It is important to be aware of the time course of altitude acclimatization in that it takes longer than previously thought to fully ac



climatize. Individual differences in acclimatization rates, which can be influenced by genetics, can predispose a person to be either a fast or slow responder. This refers to the time at which it takes to acclimatize to the new altitude. Being a slow responder to altitude may necessitate an individual to pre-acclimatize at a moderate altitude location prior to being deployed in theatre at altitude. Additionally, altitude acclimatization research has emphasized the importance of considering physician-supervised iron supplements if one becomes iron deficient upon taking residence at altitude. This has direct application to cadets, including those involved in athletic competition. The indirect evidence of neocytolysis, or the breakdown of young red blood cells when you go from a higher altitude to a lower altitude, has brought to light the de-acclimatization that occurs over such temporary sojourns as winter break. When cadets return to altitude from sea level, their performance on aerobic-based activities is somewhat compromised. Recent research has indicated that higher intensity and/or duration exercise performed while at sea level can buffer the loss in hemoglobin mass and subsequently reduce the loss in performance.

Nelson said that cadets participating in research can be provided a perspective of opportunities available post-graduation. Cadets can understand that the idea of research is to investigate and seek out pieces of the puzzle—to further explain concepts and principles that further add to the knowledge base.

“Research at USAFA is just another element that contributes to developing leaders of character. It further supports the concepts of integrity first, service before self, and excellence in all we do. The human performance lab seeks to continue providing research opportunities to cadets in order to further support the mission of USAFA,” he added.

INSTITUTE FOR INFORMATION TECHNOLOGY APPLICATIONS

The Institute for Information Technology Applications (IITA) is an Air Force research institute comprised of six independent research centers, and directed by General James P. McCarthy, USAF, Retired. According to General McCarthy, “the driving concept of the Institute formed in 1998 was to provide opportunities for multidisciplinary research that would be of value to USAFA, the Air Force and the Department of Defense.” IITA’s vision is to serve as a renowned Air Force research center for operational and educational information technology application. Several projects have been highly successful and have won Air Force- and DoD-wide attention this year.

The Airdrop Enhanced Logistics Visibility Information System (AELVIS) Program, directed by Lt Col Freddie Rodriguez, blends multiple technologies to provide airdrop bundle situational awareness data to warfighters. In light of Air Mobility Command’s (AMC) delivery of more than 80 million pounds of cargo via airdrop in 2011, AELVIS has been heralded as a force-multiplier, particularly for airdrops

to highly mobile units on the move. This year, AELVIS was included in the AMC-AFRL (Air Force Research Laboratory) Precision Airdrop Flagship Capability Concept baseline and was singled out by the AMC Commander as a “MacGyver” solution for warfighters. The project was fully funded by AFRL last year and after several successful demonstrations this year, AELVIS is positioned to deliver the initial installment of this cutting edge capability in FY13.

The Unmanned Aerial Surveillance—Remotely Piloted Aircraft Program (UAS-RPA), directed by Lt Col John McCurdy, has made great progress over the past year in its mission to develop cadet leadership within a relevant and realistic training environment. The program provides faculty and cadets with UAS-RPA academic knowledge, experiential learning, operation familiarization and a research foundation to support Air Force combat operations and future development of unmanned systems. In FY12, this one-of-a-kind airmanship program transitioned into fully cadet-led operations. This year, 42 cadet instructors led nearly 300 underclassmen through three levels of UAS-RPA

training including: familiarization, basic operations and mission planning and execution. The program also began integration with USAFA summer expeditionary and survival/evasion skills training in Jack’s Valley.

The Warfighter’s Edge (WEde) team is directed by Lt Col Andy Berry, a warfighter and visionary for a suite of products centered on mission planning. Using robust and easy to use tools, the WEde products maximize warfighter effectiveness while minimizing requirements for new training and equipment. This year, the program created WEdeNET using a service-oriented architecture. WEdeNET is the backbone for a secure file transfer capability on Air Force classified networks and will provide the foundation for distributed mission planning applications. The WEde team also took on two other initiatives enabling collaboration. WEde adapted a mission planning route translator enabling operators using disparate tools to share route information. Additionally, the WEde Shuttle was used in distributed UAS-RPA collaboration experiments with the F/A2Q MAESTRO suite of tools.



The Geospatial Technology Center (GTC), directed by Lt Col Charlie Gaona, has a rich history that includes the development of GeoBase and a portable Google Earth server. Recently added to the GTC, the Warfighter Geospatial Center (WGC) is a centralized source for portable Google Earth globes and servers for Department of Defense (DoD) operators. This year, by leveraging the DoD High Performance Computing (HPC) centers, the WGC delivered more than 300 portable globes and 10 Google Earth servers in support of intelligence, unmanned aerial systems, and other operations. The Virtual Operations Center (VOC) is a low-cost, web-based, common operating picture tool for Emergency Management personnel. Based on Microsoft SharePoint to maximize familiarization

and minimize training, the VOC provides real-time situational awareness to all base users. This year, the VOC was fielded at Buckley Air National Guard Base, Cheyenne Mountain Air Force Station and the USAF Academy where it is being used for day-to-day operations and events like graduation and football games.

The Wing IT Services Engineers (WISE) team is a technical leadership lab for the Wing Communications Officer and six additional cadets. Ms. Carolyn Dull mentors these cadets as they tackle real-world challenges affecting the USAFA mission. This year, the team took on some exceptionally difficult challenges. In a feasibility study, C1C Josh Christman developed an iPhone application enabling cadets to sign in, sign out and check records remotely. One of the greatest success stories of the year was an automated cadet vehicle registration and parking management system. The cadets developed a Microsoft SharePoint-based system that provides cadets and their leadership 24/7 access to service. According to Ms. Dull, “The cadets did a fantastic job! They addressed one of the Commandant’s most urgent needs, and they did it on-time with a tool that costs the Academy nothing.” Because of their success, the Commandant approved adding five cadets to the WISE team for software maintenance.

The Scholarship of Teaching and Learning (SoTL) program, directed by Dr. Lauren Scharff, harnesses the diverse and enthusiastic Academy faculty to research and implement innovative and effective approaches to cadet learning. With a generous gift from Mr. John Martinson, SoTL researchers launched more than 20 research projects during FY 12. Faculty from all four academic divisions led projects and some resulted in bringing new technology directly to the classroom.

INSTITUTE FOR NATIONAL SECURITY STUDIES

The Air Force Institute for National Security Studies (INSS) has focused research, published reports, and developed leaders with strategic knowledge and perspective for 20 years, and it is well-positioned to continue to support Air Force interests in enduring and emerging strategic security issues. Housed within the faculty at USAFA, INSS reaches out across the USAFA faculty and the broader military academic community to conduct research and to bridge the academic, think tank, and government policy communities on strategic issues. Led by Dr. Jim Smith since 1998, the INSS mission is to guide research on enduring and emerging strategic security issues, and to provide outreach through publications and workshops to convey the lessons of that research. The Institute also seeks to develop policy knowledge and analytical skills to help build military officers, and the faculties that educate them, with enhanced strategic knowledge and skills.

Across academic year 2011-2012, INSS focused on two primary areas: USAF support to regional

extended deterrence and assurance, and strategic policy education and development. INSS hosted three interactive workshops in Washington DC on regional extended deterrence and assurance. In June 2011 INSS hosted a workshop, "Extended Deterrence and NATO/Europe." The workshop combined unclassified and classified discussion on the United States commitment, varied allied perceptions of assurance, and the USAF roles in advancing this mission set into the mid-term future. INSS followed-up on this effort with support to a workshop hosted by the US Army and US Navy War Colleges on "Tactical Nuclear Weapons and NATO." The Army War College published the collected presentations from that workshop in a book of that same name, and two of the INSS staff were represented in that publication.

A second INSS workshop, "Extended Deterrence and Northeast Asia," was hosted in September 2011. This workshop used the same unclassified/classified format as for NATO/Europe, and it too engendered active and continuing discussion

among the various principals and informed the USAF on its continuing challenges in this important theater. The third workshop in the series, "Extended Deterrence and the Middle East," was hosted in April 2012. It was also timely and useful to the Air Staff planners. A fourth series workshop focused on extended deterrence and arms control will be held in 2013. INSS is combining the four individual workshop reports and publishing a consolidated report on Extended Deterrence and the USAF. According to Mr Richard Benson, Chief of the USAF International Treaties and Agreements Branch, "These workshops provide the perfect forum for consolidating our understanding of what the USAF needs to plan for, what capabilities we need to develop and maintain, and what we need to protect in arms control negotiations to be able to continue to fulfill our mission."

In the area of strategic policy education and development, INSS developed and presented its first Strategic Policy Overview in August 2011 in Washington DC to incoming Pentagon action officers



and newly assigned Unified Command Treaty Compliance Officers from the USAF arms control community. INSS then repeated the course in September 2011 in Colorado, this time for a select group of graduate students and new PhD recipients from across the country, including faculty from the Air Force Academy, the Military Academy, and the Naval Academy. This event was also our third annual Junior Summer Strategic Seminar. INSS then presented the course in March 2012 at the Defense Nuclear Weapons School for faculty development for their faculty and

the training staff of the USAF Nuclear Weapons Center. This will be a continuing program with two offerings planned each year.

The INSS Director believes, "The USAF has a continuing and essential national tasking to retain and advance strategic expertise as long as the nation retains deterrence requirements. INSS will be one of the players in maintaining that strategic expertise and ensuring a continuing 'bench' for the USAF."

LASER & OPTICS RESEARCH CENTER

In a world where directed energy and optical information technologies are undergoing rapid development and deployment, the Academy's Laser and Optics Research Center (LORC) is leading the way in developing and understanding new lasers, optical devices, and materials. The LORC offers a unique environment where cadets and researchers can together investigate and develop progressive ideas for the Air Force, Department of Defense and industry partners.

The center, supported by 11 full-time researchers with over \$7 million in advanced research equipment, is one of the most extensive, well-funded undergraduate laboratories in the United States. Led by Dr. Randy Knize, the LORC has become a world leader in multiple arenas of lasers and optics research including fiber lasers, holographic and adaptive optics, alkali lasers, atomic physics, metamaterials, and nanotechnology. In 2011-12, the center procured over \$2 million in research funds through competitive awards and grants from numerous agencies including the National Science

Foundation (NSF), Air Force Office of Scientific Research (AFOSR), Air Force Research Laboratory (AFRL), Missile Defense Agency (MDA), High Energy Laser Joint Technology Agency (HEL-JTO), and the Defense Advanced Research Projects Agency (DARPA). The expansive resources and advanced technological facilities available in the LORC allow cadets at USAFA to have the opportunity for a unique undergraduate research experience under the mentorship of the LORC researchers.

"The hands-on research experience cadets gain while performing investigations with LORC researchers is an invaluable tool in preparing for their careers after graduation from the Academy, whether it is graduate school or another assignment," said Knize. "Cadets find a certain excitement when contributing to innovative projects that can influence the future of Air Force weapons and technology."

The center's alkali laser research efforts led by Drs. Randy Knize, Boris Zhdanov, Michael Shaffer and Matthew Rotandaro continue to investigate the

development of new alkali lasers, scaling, and control technologies. For nearly a decade, the LORC has distinguished itself as a world leader in the understanding, development, and power scaling of diode-pumped alkali lasers (DPALs). Alkali lasers are gas lasers that exhibit high beam quality with excellent efficiency and the potential to be scaled for military applications such as an advanced tactical laser or in missile defense. A growing laser technology showing promise in power scaling, DPALs are quickly emerging as a safer, more reliable alternative to other tactical lasers used by the military. Ongoing fundamental research of modeling and experimental verification of the behavior of atomic systems in high-intensity light fields enhance our understanding of the alkali laser and begin to answer questions of power scaling feasibility of DPAL systems to higher optical powers. USAFA cadets actively participate in the DPAL project. More than 20 cadets were involved in DPAL research during the past 5 years and all of them have at least one published paper or conference presentation.

recent demonstrations showing his system is able to correct for beam distortions, such as atmospheric turbulence at speeds greater than 10 kHz.

During 2011-2012, the center's research in eye-safe fiber lasers and amplifiers based on phonic crystal fiber technology advanced rapidly. Led by Dr. Chad Carlson and funded by the HEL-JTO, cadet and faculty research led to advances in supercomputer modeling of microstructured fibers. These high fidelity models have been used to fabricate advanced microstructured fiber designs for mitigating nonlinearities and higher-order modes that are parasitic to laser operation. The mitigation of these nonlinearities will allow fiber lasers and amplifiers to serve as high power directed energy weapons for tactical applications. As part of this effort, the center developed high power pump/signal combiners for photonic crystal fibers capable of handling kW of input pump power for next generation high power fiber lasers and amplifiers. These components designed and patented at USAFA will lead to novel configurations for the next generation high power fiber lasers and amplifiers for directed energy. Additionally, several USAFA cadets and LORC researchers collaborated with Lawrence Livermore National Laboratory in a modeling/simulation effort to support their new fiber pull facility.

LORC researcher Dr. Yalin Lu is driving research in metamaterials and nanotechnology to new levels. His continuing investigations of nano-structured copper indium gallium selenide (CIGS) solar cells, a possible alternative to silicon based solar cells, have shown that writing metallic and semiconductor nanogratings on the device can improve performance characteristics like short-circuit current density by a 250% enhancement. Lu's other projects include investigations of tunable intrinsic negative index materials (NIMs), tunable plasmonic metamaterials, and high sensitivity single-atom detectors. Tunable plasmonic metamaterials, for example, offer unique active responses to terahertz to microwave wavelengths, potentially wide applicable to sensors, antenna, and cloaking in various AF tasks. Drs. Brian Patterson and Jerry Sell are also investigating plasmonic effects in various materials via an investigation of the effect of plasmonic layers in thin film silicon solar cells. The LORC's metamaterials and nanotechnology research represents examples of an emerging field that cadets have the opportunity to contribute to and that may lead to more efficient energy conversion devices or advanced optoelectronic materials capable of optical sensing, detection, cloaking or shielding applications in the future.

LIFE SCIENCES RESEARCH CENTER

The US Air Force has a fuel problem. Increasing costs by the billions annually impacts the entire budget of the Air Force and the Department of Defense. One part of the solution lies in researching and developing new sources of fuel. The Life Sciences Research Center (LSRC) is making strides towards facilitating the use of microalgae for biofuels production. Refining the scope of the center's research towards media optimization, faculty and cadets have revealed preliminarily how important prescribed nutrient and environmental factors play into biomass and oil accumulation in microalgae. This research plays a critical factor in future fuel research and adds to cadets' understanding of the current and future challenges they will face as Air Force officers.

Under LSRC Director Dr. Don Veverka's leadership, cadet research has been a driving force in the center.

In the summer of 2011, LSRC sent two cadets on Cadet Summer Research Program (CSRP) at Tyndall AFB, FL (AFRL) and Wright-Patterson AFB,

OH (AFRL) to work with scientists on harvesting and mass cultivation techniques. Cadet Mike Wojdan worked side by side with AFRL staff in creating an advanced harvesting technique for algae using electro-flocculation of algae samples. Wojdan independently developed dramatic improvements and modifications to his research plan and demonstrated the ability to appropriately design and modify experiments based on analysis of his own data. Wojdan's work was praised by AFRL staff scientists who said his research "enabled his branch to develop and demonstrate technologies that could drastically reduce the time and logistics footprint to harvest algae for deployed energy. Without his help this technology would not have been demonstrated this year, which would have postponed the deployed bioenergy effort. His work has given AFRL researchers the ability to build larger reactors that could be used in a prototype scale demonstration that will enable warfighters to potentially use deployed biologically derived energy," Cadet Wojdan's notable research efforts resulted in his selection as the 2012 USAFA Basic Sciences CSRP Award winner and he was a semi-finalist

for the USAFA Thomas D. Moore Award for Cadet Summer Research.

The center made substantial equipment upgrades including new advanced cultivation and measuring equipment to carefully analyze optimization trials. Additionally, the center attracted new research partners which bring depth and expertise to LSRC research and the cadet experience. One of these new Cooperative Research and Development Agreement (CRADA) partners, Bergstrom Nutrition, has a strong experience base in creating nutritional additives which accelerate growth in select microorganisms. The goal of this partnership is to work collaboratively towards finding an exceptional growth additive for use in our optimal algal media recipes. Another 2012 CRADA with the Colorado School of Mines, which has considerable understanding in characterizing and profiling the algal oils, will allow LSRC to further test experimental algal media blends on two particular algal strains noted for exceptional starch production. These starch products are equally important as alternative fuel products



from the fermentative aspect (ethanol) and hold great promise for producing large yields of biomass available for creating renewable biofuels.

"The School of Mines will aid our efforts in better profiling the results obtained from some of our higher producing algal strains. These new developments along with our current academic and private industry partners are anticipated to help advance our media optimization research significantly and at the same time offer our cadets an even greater perspective of government, academia and commercial industry working together," said Veverka.

LSRC also undertook a new Science, Technology, Engineering and Mathematics (STEM) partnership with a regional high school. Sara Volz, a high school junior at Cheyenne Mountain High School, joined the LSRC during the 2011/ 2012 AY, assisting the LSRC with some experiments involving environmental manipulations of select algae for biofuels. Already carrying out experiments in her home while in middle school, Volz had an innate interest in cultivation of algae and has brought with her some years of experience that belie her young years. Working with the center and Dr Timm Knoerzer of the Academy's Department of Chemistry, she has already won some local and regional science fair awards based on her recent work and is slated to go on to both national and international competitions in the later part of 2012.

The quest for stable Polymerase Chain Reaction (PCR) dye reagents aiding in the detection and mitigation of biological threats remains a high priority for molecular-based work whether in the laboratory or the field. These reagents are perishable and typically require cold storage to extend usefulness and efficacy. Under a CRADA with molecular biologist Dr Daniel Atchley of Harding University College of Pharmacy, LSRC is working on the creation of a robust PCR master mix that will remain stable under harsh field conditions and facilitate real-time analysis of biological threats in theater. Recent data uncovered by LSRC scientist Ms Melanie Grogger and C2C Craig Nowadly has indicated a stable PCR master mix may be possible depending on the PCR dye reagent used. Grogger and Nowadly's research has found that when exposed to certain temperatures, certain reagents remain stable, even at temperatures exceeding 45 degrees C. Future experiments are needed for lengthier temperature trials.

Nowadly's efforts were recognized in 2011 by the Air Force Surgeon General Lt Gen Bruce Green who in Air Force tradition, coined Nowadly for his outstanding poster presentation given during the annual Air Force Medical Research Symposium in Washington DC. Nowadly was the first ever research cadet to be singled out for this prestigious honor.

"Our cadets represent the cornerstone of our center. Their endless inquisitiveness and thirst for greater knowledge has immeasurably added to our research momentum," said Veverka. "I can't begin to count the times our cadets have mentored other cadets, led tours, gave presentations or have been recognized for their superb efforts. They are just as an integral part of our center as our staff and faculty...without a doubt!"

MODELING AND SIMULATION RESEARCH CENTER

As the costs and complexities of experimentation continue to rise and the pace of technology development marches on exponentially, scientists and engineers across the Air Force are relying more and more on computational modeling and simulation techniques to meet the needs of warfighters in timely and cost effective ways. At the Modeling and Simulation Research Center (MSRC), cadets and faculty from a nearly a dozen different academic departments perform cutting-edge Modeling and Simulation (M&S) using a brand new in-house supercomputer as well as High Performance Computing (HPC) tools located at several Department of Defense Supercomputing Research Centers around the United States. Additionally, the MSRC is actively engaged with faculty from several departments to increase the integration of M&S into the classroom in much the same way that traditional laboratory experiments have been used to help enhance the learning experience.

At the heart of every Modeling and Simulation Research organization is a computer that is tasked with

performing trillions of calculations and storing tremendous amounts of data. In November 2011, the MSRC conducted a ribbon cutting ceremony for a new SGI Altix ICE 8400 supercomputer with 12 nodes where each node contains 12 compute cores and 24 GB of RAM. Additionally, the system contains 7TB of shared storage. Because the supercomputer is administered locally, the MSRC is able to provide supercomputer access and support to cadets and faculty within the constraints of a fast paced academic environment. This truly makes the dream of bringing Modeling and Simulation into the classroom a reality and during the 2010/2011 academic year over 90 cadets used the supercomputer in computational aerodynamics and physics courses.

While the MSRC has its genesis in the Computational Fluid Dynamics research performed in the Department of Aeronautics, the Department of Chemistry has emerged as a very active partner in the Modeling and Simulation community. As part of the Chemistry Research Center's basic research study on the discovery, development, and character-

ization of energetic nanomaterials, cadets and faculty have performed computational chemistry simulations using the supercomputing capability brought online in 2011. Energetic nanomaterials are a unique class of explosive materials that are characterized by extremely high heat rates, extraordinary combustion efficiency, reduced sensitivity and represent the next generation of explosives for the Department of Defense. The analyses performed by cadets using GAUSSIAN code have afforded a one-of-a-kind, new predictive capability for more rapid experimental materials design. "USAFA is one of the only institutions in the country where undergraduates are performing computational simulations of energetic nanomaterials and it is exciting to see the impact that cadets are having on the development of these fascinating materials," said Lt Col Shad Reed, Director of the Modeling and Simulation Research Center.

In addition to supporting Modeling and Simulation Research performed at USAFA, the MSRC provides both cadets and faculty with immersive Modeling and Simulation research opportunities away from



USAFA during the summer. During the summer months of 2011, the center sponsored five cadets and two faculty researchers to conduct cadet summer research programs in Hawaii and Florida. For cadets, this experience is one of the few moments of their cadet career where they can focus on one aspect of their development without all of the competing demands for their time that they face during the academic year. It also provides a glimpse into what their careers could be like if they choose to enter into one of the Scientist or Engineering career fields after graduation. For the faculty members, they are placed alongside the cadets and help to mentor and guide them through their research projects and they are given opportunities to pursue their own research interests. Cadets majoring in



Aeronautical Engineering spent five weeks at the Air Force Seek Eagle Office located at Eglin Air Force Base, Florida and performed simulations of complex aircraft store release maneuvers using the Air Force developed Computational Fluid Dynamics code called Kestrel. As a result of their efforts, several areas for improvement were identified in Kestrel and a new version was released and incorporated into the Computational Aerodynamics course taken by all Aerospace Engineering majors. Ultimately, this tool will provide a tremendous reduction in the amount of flight testing that is required to certify a new stores configuration on an aircraft. Because of the outstanding feedback from the research sponsors in 2011, the number of opportunities to send cadets and faculty on M&S related summer research projects is expected to grow by 50%.

"As future leaders in the Air Force, it is vital that cadets be exposed to the methods and tools that will be used to advance the state of technology for the foreseeable future" said Lt Col Reed. The MSRC plays an important role in this process through sponsorship of immersive summer research projects, making state of the art computational resources available to any interested researcher and cadet, and supporting the integration of modeling and simulation tools into the curriculum. Over the next several years, the emphasis on modeling and simulation will continue to grow and become a natural part of many more research projects and extend into academic classes across USAFA. It is truly an exciting time to be in the Modeling and Simulation Research Center!

SCHOLARSHIP OF TEACHING AND LEARNING

As the 33rd best university in the nation, the U.S. Air Force Academy can boast of having a diverse and dedicated collection of instructors, highly vested in making cadet learning the number one priority. During the past three years, some of them have taken the step of engaging in the Scholarship of Teaching and Learning (SoTL), which promotes a scientific approach to understanding what works best and why, both in the classroom and sometimes out of the classroom. An added bonus is the inclusion of cadets in SoTL research. As co-investigators, cadets have an opportunity to improve cadet learning and examine engagement in specific courses. Consistent with the broader scholarship process, we encourage all SoTL researchers to disseminate and communicate their research to faculty and their peers.

Under the guidance of Dr. Lauren Scharff, and made possible by a generous gift of funding from Mr. John Martinson, SoTL researchers launched more than 20 SoTL research projects during the 2011/2012 academic year, involving faculty from all four academic

divisions. These projects fall into several categories: individual course projects, multi-course projects, cadet-led research, and institutional-level projects.

“By systematically studying what works to enhance learning, we can avoid educational fads and more widely adopt data-supported best practices,” said Scharff.

Building on work from last year, some SoTL projects incorporated a focus on the use of new technologies. For example, during the spring 2012 semester, Dr. Mark Jensen of the Philosophy Department created a completely paperless classroom. While being completely paperless is common for online courses, it is not typical for face-to-face courses. Each student was given a Fujitsu slate to use for the semester, purchased e-texts rather than paper texts, was instructed how to use electronic annotation while reading and taking notes, and received and submitted all documents online. Cadet focus group comments last year indicated that many students hesitate to annotate their paper texts, but that they were more likely to electronically highlight and annotate when they

used electronic texts. Dr. Jensen assessed differences in text annotation and performance on assignments across his different sections and collected student feedback. These results will inform future decisions regarding the use of electronic texts.

As part of the Academy’s Computer Security and Information Warfare course, C1Cs Ryan Cooney and Jacob Blasbalg worked with Dr. Steven Fulton on a project to understand the role of privacy in on-line social networking situations and to understand how cadets’ expectations of privacy related to their activities on social networking sites. The cadets collected feedback from cadets enrolled in the Introduction to Computer Science courses and performed an assessment of cadet publically available information on the most common social networking sites. The results of this project will be utilized to create a teaching tool for future introductory computer science courses.

SoTL projects are also “cutting edge” in ways that don’t involve technology. For the spring 2012 semester, Capts Timothy Frank and Josh Aldred from Civil



Engineering, along with Dr. Alice Meyers of the Department of Foreign Languages created a new interdisciplinary course in Foreign Area Studies that puts new meaning to the term “interdisciplinary.” As is common for interdisciplinary courses, this course involved three instructors who attended and actively participated in each lesson. However, in addition, more than half the lessons were led by instructors and staff from across the Academy (e.g. history, literature, political science, economics, behavioral sciences, project management, military strategy, culture, language, and engineering). Cadets were exposed to a wide array of perspectives that pertained in meaningful ways to the course’s objectives: the application of those fields to the study of Mozambique and foreign aid, the design of a

water purification method that would be appropriate for the Mozambique population, and actual delivery and implementation of their purification approach. This course approach epitomizes the development and application of high-level critical thinking that we desire for our graduates—processes they will need to bring to bear as they move into an operational environment.

On a larger scale, there were several multi-semester SoTL projects involving multiple courses. Prof John Hertel (Law), Dr. George Mastronianni (Behavioral Sciences), Dr. Andy Katayama (Behavioral Sciences) and Dr. Scharff (SoTL), began an ongoing series of studies that investigates best practices in Scholars courses and how these might be transferred to non-Scholars courses. Additionally, eight course directors from the fourth-class year continued working together to enhance foundational critical thinking skills and created a common critical thinking guide and explicit links across courses. Projects such as these support institutional outcomes and have the potential to positively impact every cadet who attends USAFA.

SoTL researchers share their projects and inspire other Academy instructors at the annual SoTL Forum, held in September of each year. They additionally share their ideas and findings via monthly SoTL Circle discussions and departmental brown bag presentations. During the AY 2011-2012, at least fifteen SoTL projects were presented at conferences, several of which had international audiences, and three project papers were accepted for publication. “The ongoing, enthusiastic involvement in SoTL research across all DF divisions illustrates the dedication of our instructors to providing the best possible education for our cadets,” said Scharff.

SPACE PHYSICS & ATMOSPHERIC RESEARCH CENTER



Echoing the Academy's Space Systems Research Center, the mission of the Space Physics and Atmospheric Research Center (SPARC) is to provide cadets real-world research experience, allowing them to "learn space by doing space."

Led by Dr. Geoff McHarg, SPARC's goal is to develop the next generation of space professionals via one-on-one research with cadets in areas of interest to the Department of Defense. Cadets learn about the space environment and how that environment affects people and man-made systems via hands-on, real-world opportunities. Cadets design, build, calibrate, and operate DoD or Air Force funded sensors and eventually analyze data using a variety of methods that probe the space environment via in situ and remote sensing techniques.

Dr. McHarg commented on the contributions by the cadets to SPARC success. "We have cadets from five different departments working with us this year. This broad range of skills has been critical to our efforts this year. Successful teams in the Air Force

don't care what your major are, they care what you bring to the fight, and our cadets are bringing their best efforts ever." The Miniaturized Electrostatic Analyzer (MESA) and Canary instruments are some of the center's success stories.

The cadet-designed and built MESA has flown on several spacecraft and provided measurements of ionospheric density, temperature and satellite charging. The most recent MESA was part of the Materials International Space Station Experiment number 7 (MISSE-7) flown to the International Space Station (ISS) in November 2009 and returned to Earth on STS-134 in June 2011. This MESA experiment was operated by cadets and faculty at the Air Force Academy using a remote ground station capability provided by the National Aeronautics and Space Administration (NASA). The MESA instrument was developed and delivered by cadets from previous classes.

In 2011-12, C1Cs Rob Raynor, Ben Rinaldi, A.J. Wallerstein, and Kody Wilson used data from MESA as the basis for their physics capstone project. Wilson

and Wallerstein attended the International American Geophysical Union (AGU) conference in December 2011 where they reported on the first results of their analysis. Rinaldi and Raynor are continuing this work, and in 2012, they traveled to Kirtland AFB to report their results to members of the Air Force Research Laboratory (AFRL).

A dozen SPARC cadets took part in the very successful Canary project during the 2011-2012 academic year. Canary is an ion spectrometer designed to measure the interaction of rocket plumes from arriving spacecraft with the ISS. Canary was built in partnership with the Johns Hopkins Applied Physics Laboratory and was delivered to the ISS by STS-134. Installed on the port truss of the ISS, and about the size of a coffee mug, the Canary is part of the Space Test Program—Houston 3 (STP-H3) experiment. C2C Brandon Mueller reported at the Fall AGU meeting on a very favorable comparison between the Canary instrument and the NASA Floating Point Measurement Unit (FPMU), located inboard of Canary on the same ISS truss. Working directly with



NASA space professionals, Canary is a great example of how cadets "learn space by doing space."

In 2011-12, SPARC cadets started development of a new experiment, Peregrine, to take images of the Sun using a deployable space telescope. A multi-disciplinary project involving several USAFA Research Centers, Peregrine uses membrane optics technology developed in collaboration with the Laser and Optics Research Center (LORC). Peregrine is the payload on FalconSAT-7 (FS-7), a very small "CubeSat" satellite. CubeSats are about the size of a canister of tennis balls, and were developed to allow university students to build satellites on an affordable scale. The CubeSat

for FS-7 is a commercial off-the-shelf satellite and SPARC cadets, in addition to developing the payload, are the program integrators.

The FS-7 and Peregrine payload is funded by the Defense Advanced Research Projects Agency (DARPA) and is being built in collaboration with students at the Air Force Institute of Technology at Wright-Patterson AFB, AFRL professionals at Kirtland AFB, and scientists at NASA's Goddard Space Flight Center. This project will see the first ever space flight of a membrane telescope and is slated for delivery to a launch provider in October 2012.

C1C Samantha Latch spent her 2011 Cadet Summer Research Program (CSRP) at Kirtland AFB developing techniques to fold the Peregrine's 20-cm diameter membrane telescope into a volume the size of an individual serving of yogurt! Latch's research has been very successful, and as part of an individual research project in Fall 2011, she briefed the concept to the Space Experiments Review Board (SERB), the senior group of space professionals that ranks proposed DoD space experiments. Cadet Latch's presentation was so well received that Peregrine obtained the highest DoD SERB ranking ever achieved by a cadet project.

The Air Force Space Command Chief Scientist, Dr. Doug Beason said "The FalconSAT-7 CubeSat currently in development by USAFA faculty and cadets will prove to be a highly innovative demonstration of space-based capabilities. The payload—solar imaging telescope with a photon sieve as the primary element—is truly revolutionary. This incredibly disruptive technology has potential applications for many Air Force Space Command operational missions, including space-to-surface intelligence, surveillance and reconnaissance, responsive space, and space situational awareness. FalconSAT-7 is a cutting edge, high-technology project providing the perfect opportunity for our future space professionals to be involved with a program of critical relevance to the Air Force."

SPARC continues to be successful in performing its mission to develop the next generation of space professionals by providing cadets the opportunity to research real projects of real interest to the DoD. SPARC faculty and cadets are becoming known as a hotbed of novel science missions for the Air Force. SPARC is supporting the overall Air Force Academy mission to educate, train and inspire men and women to become officers of character, motivated to lead the United States Air Force in service to our nation.

SPACE SYSTEMS RESEARCH CENTER

The Space Systems Research Center's (SSRC) cutting-edge FalconSAT program provides cadets the opportunity to design, build, test, launch, and operate Department of Defense (DoD) and other payloads—the sole undergraduate-only effort of this kind in the world. Combined with its FalconOPS “Space for All” program and fully-capable ground operating station, a world-class commercial-grade clean room, and USAFA faculty and research experts from the space and launch industry, this “Learning Space by Doing Space” program offers cadets of all majors the chance to work within the construct of an integrated aerospace company with real-world clients, budgets, launch deadlines, and all of the accompanying challenges.

Cadet teams in the SSRC currently operate FalconSAT-3 and FalconSAT-5, as well as continuing development of the FalconSAT-6 and FalconSAT-7—both tentatively scheduled for launch in 2015 and 2014, respectively. Now in its sixth year of operations, the FalconOPS team of more than 100 cadets operates FalconSAT-3 and FalconSAT-5 using recently improved ground station and communications complex capabilities.

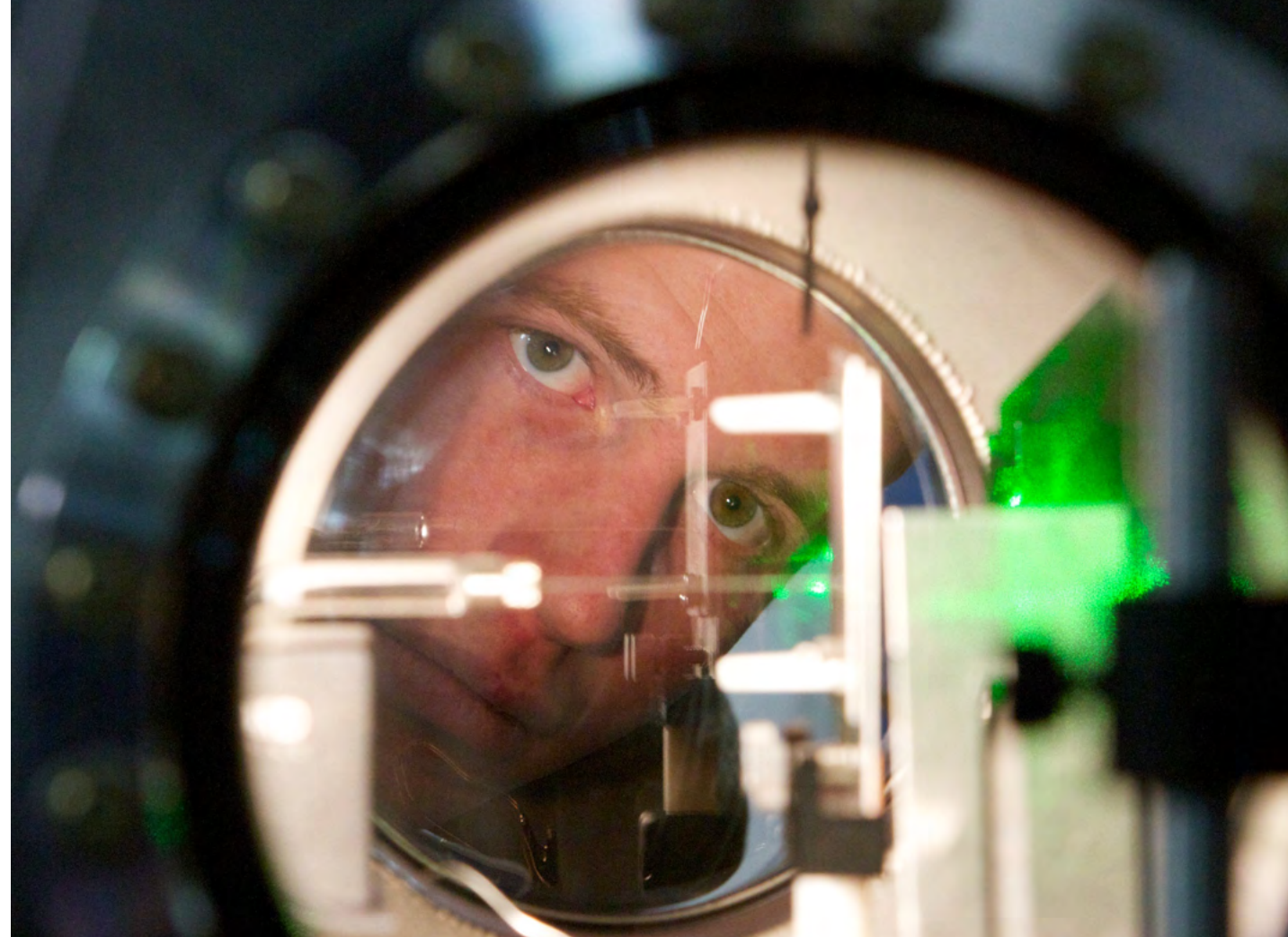
Participation in the Astronautics capstone project is a requirement for all Astronautical Engineering and Space Operations majors but cadets majoring in other fields also have the opportunity to participate, making the program truly multi-disciplinary. Colonel Martin France, Astro Engineering Department Head says “Immersing cadets in a multi-disciplinary program where they need to work as a team and respond to real-world needs that can be ambiguous—not just some academic exercise—sets this program apart. It not only pays immediate dividends for Air Force and DoD space research but also produces cadets that are far ahead of the peers in terms of experience managing and leading complex technical programs.”

One of the most successful SSRC cadet research efforts in 2012 was Cadet Jacob Krasnov's development of task executable code for FalconSAT-3. His code tackled an operating issue that had plagued FalconSAT-3 since its launch in 2007—a lack of attitude control data, which is essential to operation of two experimental payloads: a plasma sensor and a pulsed plasma thruster. Under the guidance of Academy's

General Bernard A. Schriever Chair, Professor Steve Hart, Cadet Krasnov wrote the new upgrade code which resulted in a system that now collects sun-sensor data frequently enough to monitor changes in the spacecraft's attitude, breathing new life into FalconSAT-3 operations.

In March of 2012 FalconSAT-3 celebrated its fifth birthday and Col France, expressed his pride in the program: “It took us over a month to establish contact with the balky bird, and some of the payloads and subsystems have not performed as expected, but the cadets, faculty, and staff have kept FS-3 flying, all the while solving problems and actually improving its performance.” France pointed out FalconSat-3 was originally designed for a one-year mission and he expressed hope it may make it to its tenth birthday in 2017.

In addition to successful operations missions, the SSRC has expanded its overall AF mission and officers are now able to control FalconSAT-3 from Vandenberg AFB as part of Air Force Undergraduate



Space Training and at the Air Force Institute of Technology (AFIT) as part of their graduate studies. Hundreds of cadets have also flown FalconSAT -3 in our summer space program and during the academic year.

Launched in November 2010, FalconSAT-5 has also been a successful testing ground for cadets, driving them to come up with creative solutions to on-orbit challenges. Cadets have performed more than 600 FalconSAT-5 contacts since launch. They have test fired the Air Force Research Lab (AFRL) Hall Effect Thruster as well as operated the Academy's own Space Physics and Atmospheric Research Center's Integrated Miniaturized Electrostatic Analyzer (iMESA) and Wafer Integrated Spectrometer (WISPERS) sensors.

The Center continued to enhance its capabilities during 2011-2012. The USAFA Propulsion Laboratory was built and commissioned under the leadership of Dr. Michael Holmes. Holmes, who is serving a two-year sabbatical from AFRL as a distinguished visiting professor to USAFA, brought a vacuum chamber from the AFRL Propulsion Directorate at Edwards AFB for this new facility. This state-of-the-art equipment allows cadets the opportunity to develop and test high-efficiency Electrospray Thrusters to power future spacecraft. This novel concept in spacecraft propulsion has the potential to provide efficiencies 50 times greater than thrusters in use today and may be used on a future FalconSAT.

The SSRC has established itself as a launching pad to top graduate schools for many cadets, with over 10 per year since 2006 headed to prestigious graduate schools including the Massachusetts Institute of Technology, Stanford, Rice University, Virginia Tech, and AFIT. The Center is positioned to not only contribute a generation of space professionals to the Air Force but also to become a greater part of our nation's next chapter in space operations and exploration. Cadets and SSRC alums are conducting research critical to enhancing the Air Force space mission, and leading to the development of new technologies to drive our nation's security in space, air, and cyberspace.

At the 2012 USAFA Research Awards ceremony, AFRL Commander Major General Neil McCasland summed up the Center's value by saying, “I'm here to tell you, FalconSAT is a long ball hit—I assert boldly amongst the flyers here, that it pays off more to the Air Force space mission than the academy airmanship programs do to the flying mission. It matters that much! You, who make the program work--cadets and faculty both--taste, live, breathe and solve the same kinds of challenges that we face in our Air Force Space Programs.”

SCIENCE, TECHNOLOGY, ENGINEERING & MATHEMATICS

Innovation in—and support for—Science, Technology, Engineering & Mathematics (STEM) in K-12 education is crucial to American competitiveness and national security. To meet this challenge, the Dean of the Faculty created the USAFA K-12 STEM Outreach & Research Center in 2011 to support a wide variety of STEM outreach to K-12 students and educators. The Center applies the Academy’s Core Values—Integrity First, Service Before Self, and Excellence in All We Do—to thoughtful enterprise planning and system engineering analysis to create an effective, flexible, scalable, local K-12 STEM outreach program.

“As a leader in undergraduate education for Air Force officers in STEM fields, the U.S. Air Force Academy (USAFA) has been a key contributor to America’s STEM workforce for a long time. Until recently, the Academy viewed itself as a beneficiary of K-12 STEM education at the back end of the STEM talent pipeline, but we now share the larger perspective that we must also be part of developing STEM talent at the front end of the pipeline,” says Center Director

Dr. William Crisler, who also teaches aircraft design in the Academy’s Department of Aeronautics.

The Center does not play a role in the undergraduate STEM education component of the Academy’s central mission, which is to train, educate, and inspire officers of character. Rather, it leverages and coordinates existing services, partnerships and revenue streams and marshals goodwill among local schools, local industry, and local professional societies to serve teachers and students in Southern Colorado. Using funding from local industry and the National Defense Education Program (NDEP), the Center coordinates, supports, and exports the Academy’s world-class STEM capability into the local community and exploits its world-class venue to support other agencies (e.g., US Navy, NASA, Federal Aviation Administration, Air Force Association, American Institute of Aeronautics and Astronautics, etc.) in their STEM outreach missions.

The Center has developed a comprehensive regional enterprise and sustainment strategy which balances

support to STEM teachers with programs tailored for children of all ages, demographics, and interest levels. The Center also partners with regional non-profit organizations and local industry to provide STEM opportunities beyond those in the classroom for thousands of K-12 students annually. Other communities can exploit that model to create their own solutions to match local resources to local economic and educational objectives.

“The mind is a fire to be kindled, not a vessel to be filled.” The words of Plutarch echo in today’s modern classrooms nearly 2,000 years later and are reflected in the sustainable, hands-on, project-based experiences and programs promoted by the Center. K-12 students are offered “kindle the fire” experiences, hands-on project workshops, and live demonstrations at USAFA and in their classrooms. To sustain the “fire” of interest in STEM once kindled, teachers are given tools, access to resources, training, and opportunity to create and manage their own STEM programs, which will serve thousands of students over the course of their careers. The Center’s annual



K-12 STEM Educator Summer Bootcamp (a 3-day training session that showcases a variety of project-based STEM activities) encourages and enables teachers to become the STEM enterprise managers at their schools.

Via a dynamic partnership with The Colorado Consortium for Earth and Space Science Education (CCESSE), the Center directly supports a variety of regional STEM programs. Local expressions of national programs include Challenger Learning Center, Sea Perch, Project Lead the Way, Real World Design Challenge, CyberPatriot, and FIRST Robotics. Locally-developed programs include Cool Science (an exciting chemistry “magic show” outreach to schools and youth organizations) and Peak Area



Leadership in Science (a social network for science teachers and an essential component of any local STEM outreach solution). CCESSE also collaborates with local school districts to create an innovative, cost-effective assessment environment for K-12 STEM programs.

The Center supports and coordinates STEM outreach by USAFA’s academic departments, individual faculty, and cadets. For example, the Department of Physics is typical in supporting multiple efforts for the local community, including its popular “Physics is Phun” and Astronomical Observatory Programs. Departments support more than 10,000 regional students who visit our various research centers and laboratories annually. The Cadet STEM Outreach Club was created in 2012 by Victor Lopez, a cadet majoring in astronautical engineering. Cadets support USAFA STEM outreach via judging at local science fairs, giving live STEM demonstrations to local school groups, and supporting STEM visits and events all over the region.

Dr. Crisler concludes by saying, “The key to solving the national STEM workforce crisis for America is a widespread, loosely-connected network of effective, flexible, local or regional solutions, not more top-down, directive, one-size-fits-all programs. The Pikes Peak region and southern Colorado make an ideal proving ground for the collaborative model and pilot program we’ve developed for K-12 STEM outreach.”

USAFA CENTER FOR ORAL HISTORY.

As the sun rose against the Rocky Mountains on September 11, 2001, Lieutenant Colonel Tim Conklin, USAFA Class of 1988, had no idea what would happen that day. Originally slated to join his wing commander on a check ride, within a few hours after arriving at Buckley Air Force Base, he found himself strapped into his F-16 on a combat mission, patrolling the skies over the USAF Academy, Peterson Air Force Base, and Cheyenne Mountain. As he took off, he acknowledged an eerie message from the controller who usually monitored a busy frequency . . . “You are the only traffic in the state of Colorado; you are cleared all altitudes. Thank God you’re here.” Within a few short months, Conklin would be taking his 120th Fighter Squadron to the Middle East to fly in the first of a series of deployments in support of Operation ENDURING FREEDOM. Although Lieutenant Colonel Conklin’s story is a drama-filled tale that took place on one of the most shocking days in recent American history, his recollections, and the recollections of other USAFA grads like him, form a rich legacy of Academy heritage that is being pre-

served by research efforts carried out by the USAFA Center for Oral History.

Entering its third year of operations, the USAFA Center for Oral History continues to enjoy considerable success in carrying out its primary mission of preserving the history of the U.S. Air Force Academy through the voices of the people who experienced it. Building upon earlier oral history efforts conducted by the Department of History and on behalf of the Friends of the Library, the center believes its role of preserving yesterday for tomorrow’s profession of arms is of lasting importance to the larger USAFA mission of developing future leaders of character for the United States Air Force.

“Every USAFA cadet has an important experience to share with future generations,” opines Dr. Bob Wettemann, Director of the USAFA Center for Oral History. “Whether that story inspires another, offers a leadership lesson, or demonstrates core values of integrity, service and excellence, it is worthy of being recorded.” To these ends, the USAFA COH has con-

tinued to record the accomplishments and exploits of USAFA graduates. In addition to Lieutenant Colonel Conklin, recent interview subjects have included Brock Strom (‘59), Lt. Gens. (ret.) Jay Kelley (‘64) and Michael Short (‘65), Astronauts Fred Gregory (‘64), Richard Covey (‘68) and Brian Duffy (‘75), as well as recent USAFA Rhodes and Truman Scholars, and Cadet Wing Commanders.

But the center is not only interested in preserving these narratives. It is also firmly committed to ensuring that current USAFA cadets have access to, and make use of this material by cadets for their own research and publication. Dr. Wettemann currently serves as course director for History 230: Historiography and Research Methods, a requirement for all history majors, and has taught this course previously. Whereas cadets in the past were given wide-ranging latitude in developing their own research projects, Wettemann now provides cadets with the resources collected by the center for thematically-related research projects. Since taking over the course, cadets have used oral history resources to



study the history of USAFA, trace the involvement of USAFA graduates in Operation ALLIED FORCE, chart the construction of the USAFA Chapel and the challenges posed by ensuring the free expression of religion at a federal institution, and celebrate the triumphs and tribulations of African-American USAFA cadets. The goal is to not only transform these into cadet-authored publications, but to continue this model in the future. “We are currently engaged in a number of long-range projects that will continue to bring attention to cadet research in the social sciences,” Wettemann explained. “Working in concert with the Department of History’s Air Power course, we are conducting interviews with members of the Colorado National Guard’s 140th Wing, the ‘Mile-High Militia,’

based at Buckley AFB, one of the first F-16 squadrons deployed during Operation Enduring Freedom.”

A request by the American Institute of Aeronautics and Astronautics also sparked a new effort to chronicle the history of Aero and Astronautics at USAFA. When asked by the Institute to assist their own membership in providing some “best practices,” for conducting oral history research at their upcoming annual meeting, the center realized the value of conducting a similar research effort at USAFA. Not only would this oral history project capture a more personal record of USAFA-conducted technological innovations like FalconSAT and the origins, development and accomplishments of the Frank J. Seiler Research Laboratory, but it offers an opportunity to build an all-important bridge between social science and STEM education. “Preserving this record of scientific achievement and putting it in terms that everyone can understand is important,” agreed Colonel Mark K. Wells, Permanent Professor and Head of the Department of History, where the center is currently housed. “By making the past, present and future history of USAFA available, we can ensure that these contributions will endure and will be remembered by members of the “Long Blue Line.”

To ensure this lasting utility, the USAFA Center for Oral History continues to pursue endowment and other funding opportunities to sustain its operations over the long term. In addition to support from the Class of 1980 to conduct interviews emphasizing Moral Courage, the COH has entered into a partnership with the Class of 1963 to assist with their larger Class History Project. The Class of 1963 has committed itself to a larger giving campaign to support that project, and the COH hopes to benefit from their largesse in the future and take whatever steps necessary to ensure that that class will provide a perpetual legacy for future generations of cadets.

FUNDING STATUS FOR RESEARCH AT USAF ACADEMY

Research at the United States Air Force Academy continues to be a highlight of the cadet experience and has promoted an environment enabling cadets' critical and analytical skills as well as shaping their future job prospects. The funding doesn't truly indicate the value for the thousands of cadets exposed to cutting-edge research opportunities in these programs. Officer training happens in the labs as they learn the negotiation and relationship skills required of tenured program managers. The only way for this to take place is in a lab environment with entrepreneurial spirit like the research centers at the Academy. When the funding impacts a cadet's ability to conduct research then he or she quickly absorbs the business mindset from which future officers benefit. Financial support is still high, despite a decrease from year's past. Funding arrives from two primary vehicles—the first vehicle being the Memoranda of Understanding (MOU)/Memoranda of Agreement (MOA) with Air Force, Department of Defense, and other federal agencies. The second vehicle is the Cooperative Research and Development Agreement (CRADA); used for research collaborations with non-federal entities. Whether it is for a cadet's senior capstone course or an intriguing independent study in their field of interest, these funding vehicles allow every cadet the opportunity for exposure to an array of research projects.

The research program has a total value of \$58.2 million for the 2011-2012 Fiscal Year (FY). This can be broken into three main categories: External In-Kind, External Funding, and Internal Support (See Figure 2). External In-Kind support includes the value of visiting researchers and in-kind supercomputer time contributed by the Department of Defense High Performance Computing Modernization Office, which totaled \$9.25 million. External funding is the direct monetary funding that research centers receive from outside partners, pulled in from the Department of Defense (DoD), other government sources and non-federal entities. The Internal support value is determined by an evaluation of USAFA-provided laboratory facilities, USAFA personnel time, and totaled \$11.8 million.

Figure 1 indicates the sources of external funding. Outside partners contribute to the continued overall growth rate since 2001. Agreements between USAFA's Center for Aircraft Structural Life Extension (CASTLE) and the Life Cycle Management Center continue to support research on the KC-135 project. USAFA's Center of Innovation (CoI) and Department of Homeland Security continue a multi-year endeavor to enhance the Rare Event Scenario. USAFA continues to receive core funding from the Air Force Office of Scientific Research (AFOSR), the basic research manager of the Air Force Research Laboratory.

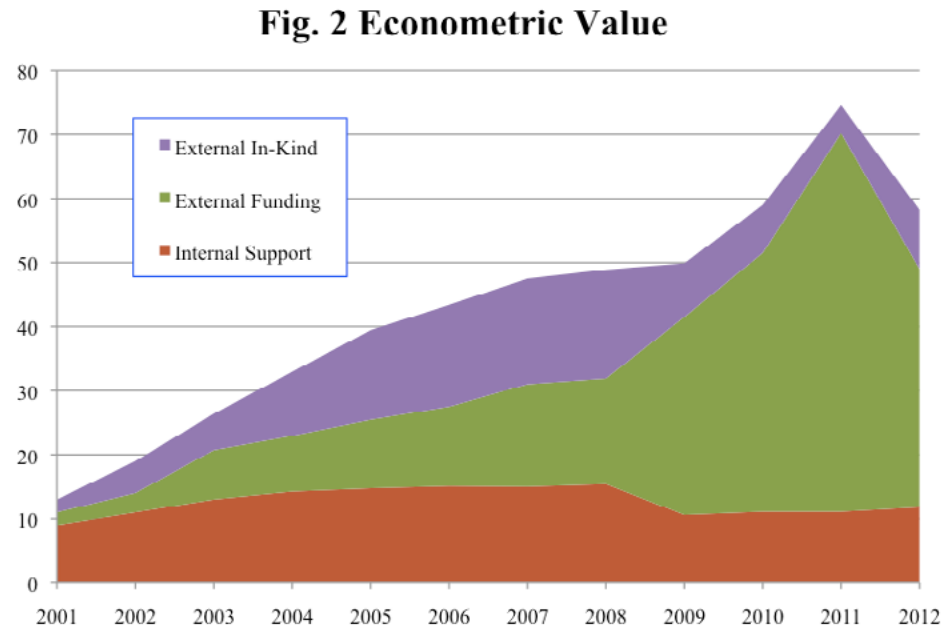
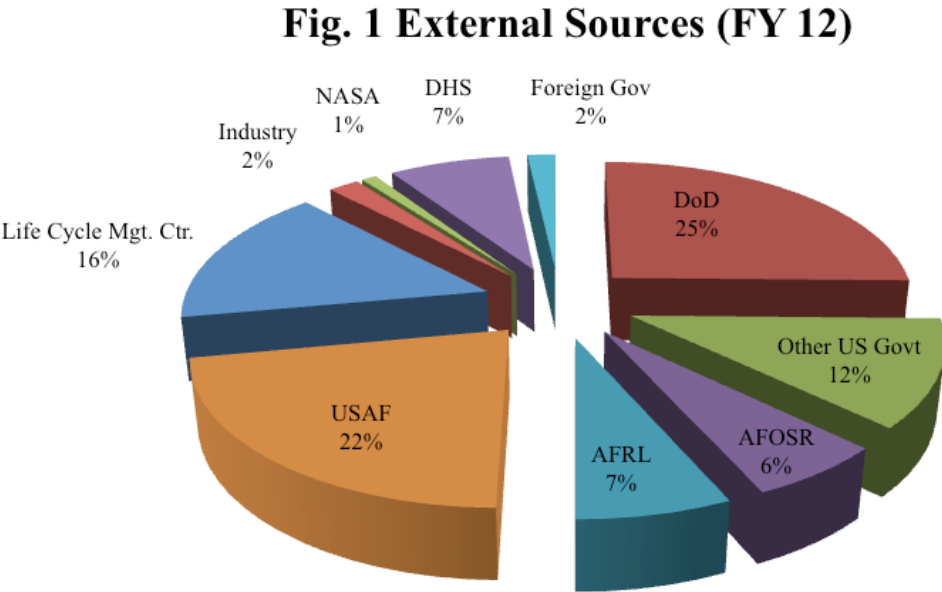


Fig. 2: Values as of 31 August 2012.





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